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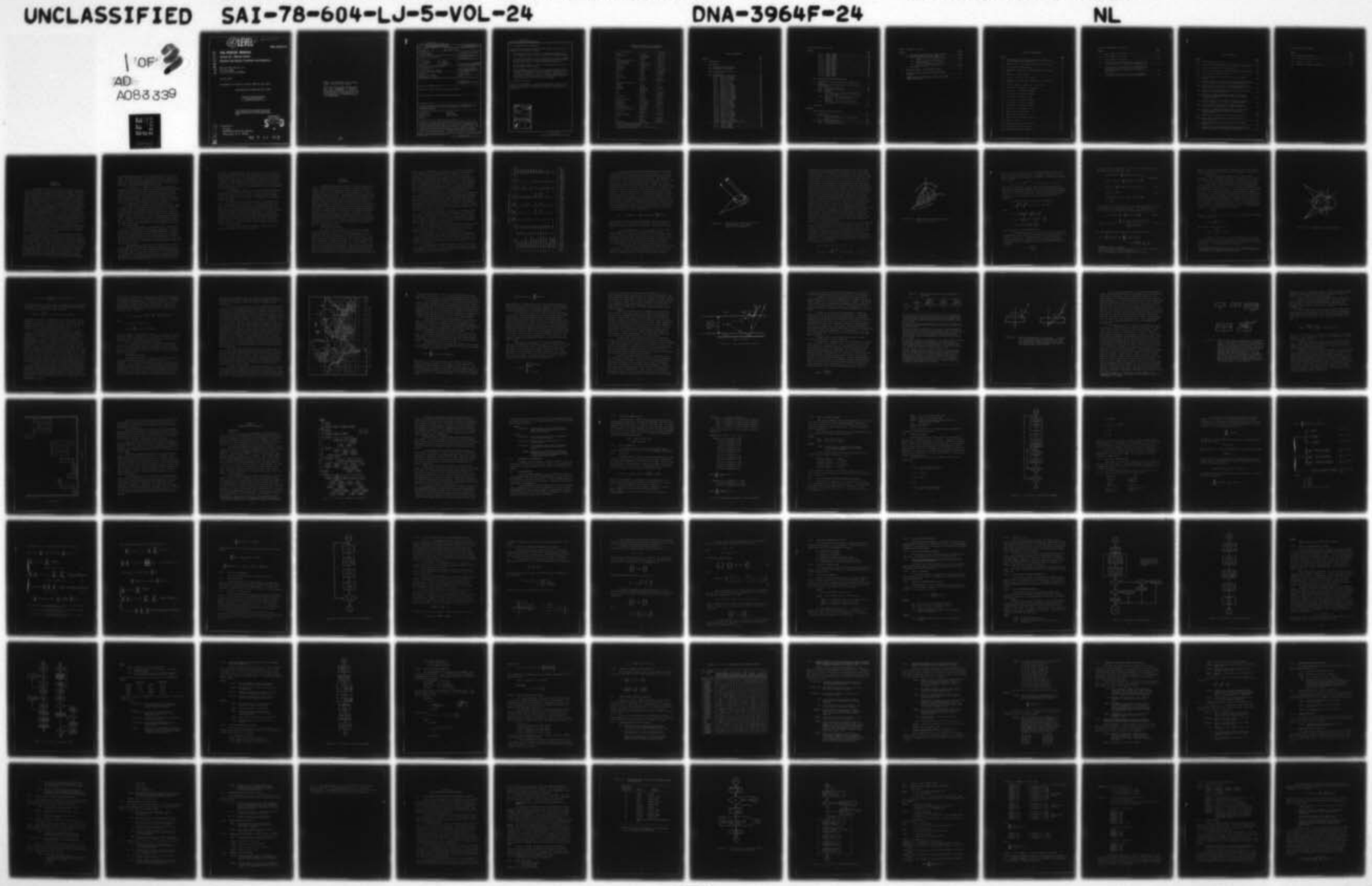

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Volume 24—Natural Clouds

(Physical and Optical Properties and Statistics)

Science Applications, Inc.
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31 July 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effect of natural clouds on IR observables from nuclear explosions is modeled for the wavelength range from 2 to 5 microns. A computer code for use with the ROSCOE-IR main program is provided to allow evaluation of the radiance resulting from transmission and reflection by natural clouds. Mie scattering cross-sections are calculated and used to generate transport cross-sections and bidirectional reflectance coefficients. Cloud transmission is treated by diffusion. A deterministic model allows the user to

18. SUPPLEMENTARY NOTES (Continued)

Incorporation of the Natural Cloud Model into ROSCOE-IR has led to a few differences in the coding, including:

1. The deletion of subroutine CLOUD1 in ROSCOE-IR and placement in subroutine CLDGEOM of calls to entry point CLDETOC in subroutine CLOUD9.

2. The recent establishment in the Cloud Model of a new subroutine CONVERT and the incorporation of the previous subroutines CTTOPOL and POLTOCT as entry points therein (a change not adopted in ROSCOE-IR).

3. The retention in ROSCOE-IR of the older name ALBEDO for a subroutine renamed CLDBDR in the Cloud Model.

4. The replacement of the calculation of the emission radiance in the deterministic cloud submodel by the calculation of only the emissivity, resulting in the deletion in subroutine CLOUD3 of PLANK(AA,TT) as an arithmetic function and as a factor in computing ESAVE and EMISS (each occurs twice). ROSCOE-IR has left the calculation of the emission radiance unaltered in the statistical cloud submodel.

20. ABSTRACT (Continued)

specify the cloud geometry. A statistical model allows selection of geographic weather averages and generates the probability distribution in radiance coefficients. Solar radiation and natural cloud thermal emission are treated.

Conversion factors for U.S. customary to metric (SI) units of measurement.

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	*giga becquerel (GBq)	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t°f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbs avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	**Gray (Gy)	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

SECTION 1
INTRODUCTION

The ROSCOE-IR computer program provides a means for calculating IR observables from nuclear detonations (NUDETS). The general computational scheme in ROSCOE is to calculate the radiance along a line-of-sight (LOS) from the arbitrary location of the sensor looking toward the NUDET source region. By projecting a number of lines-of-sight to the source and its vicinity, it is possible to construct an image for imaging type sensors. For non-imaging sensors with finite field-of-view (FOV), it is possible to assess the radiance transmitted directly from the source and separately to assess the contribution at the detector of backgrounds and scattering contributions along the lines-of-sight not leading directly to the source. In each case, the NUDET source is modeled as a function of time and wavelength and the radiance along the LOS is calculated by integrating along the LOS toward the source. The transmission of the medium and the contribution to radiance by differential elements of the LOS through emission and scattering into the LOS are taken into account. Contributors to the radiance are thus NUDET source radiation at the end of the LOS; emission of the atmospheric elements between source and sensor; and scattering into the LOS of solar radiation, earth-emitted radiation, and NUDET radiation from source points off the LOS.

The presence of natural clouds in the atmosphere influences the observable IR radiance so strongly that the inclusion of a cloud model in the ROSCOE-IR program is essential for the realistic assessment of IR observables. In most areas of the world of interest in connection with nuclear explosions, clouds are present about two thirds of the time and, in fact, clouds will lie in a LOS about one half the time. Clouds produce several kinds of effects which are important both to imaging and non-imaging sensor systems. The most obvious effect of clouds is to obscure the source or to so reduce its intensity that it is not detectable by the sensor. Thick clouds provide direct attenuation factors as high as 10^4 or 10^5 even at the most transparent wavelengths.

In wavelength bands where there is strong absorption, such as at 2.7 microns, attenuation factors of this sort occur even for rather thin clouds. This attenuation by clouds has led to the well known rule of thumb that at many wavelengths NUDETS are not visible from above until the nuclear cloud has risen through the cloud tops.

A second effect of clouds even at moderately transparent wavelengths is to destroy the image of the source by multiple scattering so that the apparent source, when viewed from above, is a circular diffuse spot on the cloud top which may be many kilometers in radius. As the nuclear cloud rises, this diffuse source becomes smaller in radius, turning gradually into the nuclear cloud itself as it emerges from the cloud top. Many seconds typically are involved in the rise of the nuclear cloud from low altitudes to cloud-top altitudes.

A third effect of clouds arises in scattered or broken clouds so arranged that one cloud obscures the direct LOS to the source, while other LOS's lead to cloud edges which are illuminated by the source. Since cloud-edge reflections may contribute greater radiance than that produced along an obscured LOS, this effect gives rise to a number of lighted clouds in the vicinity of the source brighter than the (obscured) source. Other effects of clouds include a higher background radiance than in the absence of clouds because of the high albedo of cloud tops for solar radiation and a spottiness in the background when the clouds are scattered or broken.

It has been the purpose of the ROSCOE natural cloud project to provide a cloud model and the capability in ROSCOE-IR to calculate cloud effects on systems which look at NUDET environments. Satellite systems, particularly, have been kept in mind during the development of this natural cloud capability and the spectral dependence of effects has been sufficiently treated in the 2- to 5-micron region in order that realistic results will be provided for sensors whose spectral sensitivity lies within this range.

The complexity of clouds and the variability of cloudiness in a given region poses an immediate problem in cloud modeling. It is typical that any choice of cloud configurations used for transmission calculations leads to criticism by some reviewer. Such questions arise as, why does the cloud obscure the source when it is quite likely that the source will be visible through breaks? What would be the effect if the source were half obscured and half visible? Why worry about the

brightness of illuminated clouds when the direct view of the source will be so much brighter? Why worry about obscuration of the fireball when waiting awhile will allow it to break through the clouds? Each user who contemplates cloud effects tends to think of configurations which lead to maximum or minimum impact on a system and tends to focus on worst cases or best cases. Each possible cloud configuration has some validity in the problem, but a measure of the likelihood of the case is important for overall assessment.

For the ROSCOE-IR program a cloud-effects capability has been provided which allows the user to specify, within limits, the cloud scene of his choice so that the effects of scenes which he considers likely to be important can be assessed. This capability is called the deterministic model.

In addition to the deterministic model, a statistical cloud model, based on historical observation, is provided for ROSCOE. Frequency of occurrence of cloud types and average descriptions of the properties of each of the cloud types are obtained from a global cloud study and data bank prepared for NASA (Reference 1). By the use of this statistical natural cloud model, the ROSCOE program calculates the probability distribution for radiance along a LOS and thus determines the extremes in radiance which may be exhibited in the presence or absence of clouds. For a problem which has been done by the deterministic mode, the likelihood of such a result based on natural cloud occurrences can be judged.

The physical and geometric treatment of these two cloud models is described in the following section.

SECTION 2
CLOUD MODELS

The ROSCOE-IR program performs very detailed calculations to determine radiance along the line-of-sight to a sensor. The exact geometric location of the sensor and sources including the sun, the earth's surface, and the composition of the atmosphere as a function of location are taken into account. The radiance may be calculated at any wavelength selected in the 2- to 5-micron band. Source spectral powers, absorption and scattering cross-sections, reflectivities, and other physical properties affecting radiation transport must be known in detail as a function of wavelength. A cloud model for use in conjunction with ROSCOE-IR must thus have the same detailed physical and geometric description to enable these calculations to be performed with clouds in the scene. The deterministic and statistical cloud models have been so constructed that each calculation is made in the presence of clouds sufficiently described in physical properties and geometry that such detailed transmission calculations can be performed. For the statistical clouds a whole set of such calculations is done within the cloud model and selected fractiles of the integral distributions of results so obtained are provided as output.

2-1 DETERMINISTIC CLOUD MODEL

The introduction of deterministic clouds into the NUDET environment involves a specification sufficiently complete to allow radiation transmission calculations. Various deterministic cloud shapes have been used in other radiation transmission programs. These include modeling of clouds by horizontal slabs; spheres; hemispheres; round, rectangular, and hexagonal prisms; etc. For the ROSCOE natural cloud routines we have chosen ellipsoids. By the specification of the three axes, these may vary from spherical shapes to elliptical pancake shapes to very elongated rod-like shapes. The three axes are required to lie in the vertical direction and in the horizontal plane and the orientation of the longer axis in the horizontal plane must be specified.

Location in three dimensions of the center of the ellipsoid then completes the specification of the geometric cloud boundary. Any number of clouds up to 20 are permitted in the scene so long as they are not intersecting. This deterministic placement allows the investigation of the effects of obscuration of the source by clouds, the brightness and extent of illuminated cloud edges, and the brightness of edges surrounding a hole through which the source is viewed. The cloud type which is being represented is also identified as one of the naturally occurring types so that the water droplet density and size distribution may be specified. A sample obscuration case is described in Section 4.

Transmission calculations for both deterministic and statistical cloud models have been done by diffusion. The absorption and scattering cross-sections for the water droplets and the scattering phase functions have been calculated (Reference 2) by the Mie theory of scattering of photons by spherical droplet distributions. The droplet size parameters from Reference 1 (Table 6-1) were used and are given in Table 2-1. These mean radius and variance values were used to generate a gamma distribution in droplet size for each cloud type.

Such calculations were made for droplets in the range of radii for 4.5 to 10 μm for which Mie phase-function parameters were readily calculable. These sizes are characteristic of droplet sizes for cloud-types 1 through 10 in Table 2-1. The Mie-theory parameters for 40-μm radius droplets are extremely difficult to calculate and were regarded as being beyond the scope of the investigation.

The so-called 40-μm droplets are in the usual situation actually ice crystals. The approximation of simulating such large crystals by spherical droplets would be dubious, since the dimensions are large enough that irregularities are several wavelengths in size.

The application of the usual scattering and/or diffusion concepts would be seriously complicated by the fact that such crystals are typically spatially oriented, i.e., their axes tend to be aligned. For example, in diffusion this would imply an anisotropic medium, not just anisotropic scattering.

For these reasons Mie-theory parameters were not obtained for cloud-types 11 through 14. Instead, we idealized the droplets as being 40-μm radius water droplets and employed small-wavelength approximations as described at the end of Section 3-2.16.

Table 2-1. Cloud properties by type.

	Type		Layer	Base (km)	Thick (km)	Top (km)	n (cm^{-3})	$\overline{r}$ (μm)	σ_r (μm)	Composition
1.	Cumulus-1	Cu1	Low	.5	.5	1	30	5.5	1.	Water
2.	Cumulus-2	Cu2	Low	1	3	4	70	8	2.	Water
3.	Cumulus-3	Cu3	Low	4	.5	4.5	30	6.5	1.	Water
4.	Stratocumulus	Sc	Low	.3	2	2.3	100	4.5	1.	Water
5.	Stratus	St	Low	.15	1	1.15	150	5	2.	Water
6.	Cumulonimbus-1	Cb1	Low	.5	.5	1	30	5.5	1.	Water
7.	Nimbostratus	Ns	Low	1	3	4	70	5	0.5	Water
8.	Altocumulus	Ac	Mid	2	5(4)*	7(6)	30(40)	4.8	0.5	Water
9.	Altostratus-1	As1	Mid	2	4	6	70	6	0.6	Water
10.	Cumulonimbus-2	Cb2	Mid	1	9(5)	10(6)	70(120)	10	1.	Water
11.	Cumulonimbus-3	Cb3	High	10	2	12	1	40	10.	Ice
12.	Altostratus-2	As2	High	6	4	10	10	40	10.	Ice
13.	Cirrus (Midlatitude)	Ci	High	6	3	9	.8	40	10.	Ice
14.	Cirrostratus (Midlatitude)	Cs	High	6	4	10	2	40	10.	Ice

*Parenthetical values are used in the code calculations to facilitate providing for contiguous layers in the multilayer configuration; see discussion relating to Figure 2-7 and also see Section A-4.3.

The phase functions computed from Mie theory have been used to determine the average cosine of the scattering angle, $\bar{\mu}$. From the cross sections and $\bar{\mu}$ were constructed the macroscopic transport parameters which are used in the diffusion calculations. Ten wavelength values in the 2- to 5-micron range have been selected in such a way that the principal variations in cross section are retained when linear interpolation between these wavelength values is made. The chosen wavelengths are 2.0, 2.5, 2.55, 2.65, 2.75, 2.85, 3.2, 3.5, 4.0 and 5.0. For wavelengths between these values, linear interpolation is used on the macroscopic total cross-section, Σ, the macroscopic scattering cross-section, Σ_s, and the average cosine of the scattering angle, $\bar{\mu}$. Since the absorption cross-section, Σ_a, is the difference between the total cross-section and the scattering cross-section, the necessary quantities are available to determine the macroscopic transport cross-section, Σ_{tr}, the diffusion coefficient, D, and the relaxation rate, K, which are the constants required for solution of the diffusion equation. According to the "standard" evaluation of diffusion parameters in terms of macroscopic cross-sections, we have the relations

$$\Sigma_{tr} = \Sigma - \bar{\mu}\Sigma_s (\mathrm{km}^{-1}),\ D = \frac{\Sigma_s}{3\Sigma\Sigma_{tr}}\ (\mathrm{km})\ \text{and}\ K = \left(\frac{\Sigma_a}{D}\right)^{\frac{1}{2}} (\mathrm{km}^{-1}) \quad .$$

However, that evaluation is strictly applicable only in the limit of small absorption. A more generally applicable evaluation, which we adopted for numerical results in this report, is described in Section A-1.2.

For the deterministic case the ellipsoidal boundary leads to great mathematical complexity in applying boundary conditions. The problem therefore has been treated by means of a Green's function and application of Green's theorem so that the problem is reduced to a two-dimensional surface problem. The surface integrals can conveniently be treated numerically by partition of the surface into a number of facets and summing. The general problem is treated in Section A-3.

A typical geometry for the deterministic cloud problem is shown in Figure 2-1. A point source S illuminates an ellipsoidal cloud and gives rise to radiance in the direction of a detector D. The cloud surface is naturally divided into four regions by the terminators

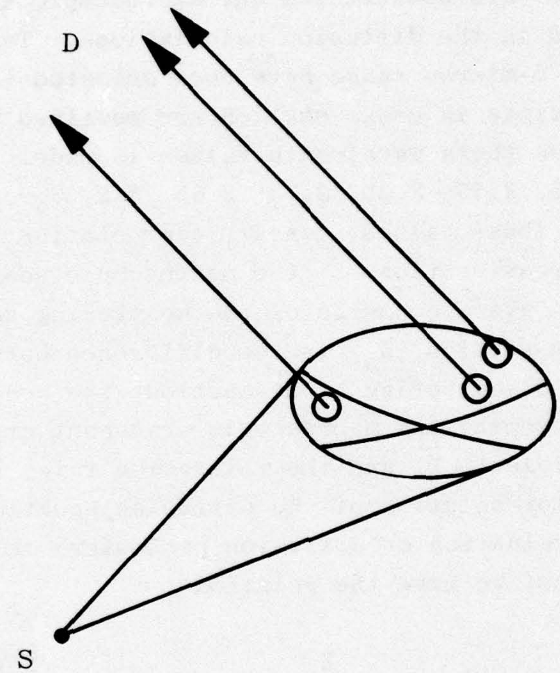

Figure 2-1. Deterministic ellipsoidal cloud model showing four regions produced by terminators.

corresponding to the source and detector points. Thus, there is an illuminated and a shadowed portion of the cloud and a visible and an invisible portion of the cloud. These combine to give four categories of cloud surface, only two of which are visible to the detector. Three lines-of-sight are shown in Figure 2-1, the lowest of which intersects an illuminated visible region while the two upper ones intersect a visible but non-illuminated region. Radiance from this latter region arises entirely from emergence of photons which have diffused through the cloud from the lower illuminated region. Although diffused photons contribute to the lowest line-of-sight also, it is in fact dominated by photons reflected from the surface. This sector of the cloud is therefore treated by bidirectional reflectance, taking into account the incident and emergent directions and the local normal to the cloud surface. Bidirectional reflectance coefficients for this purpose were calculated by Monte Carlo for a thick, flat cloud of stratocumulus (Sc) droplet density and size distribution. (This set of bidirectional reflectance coefficients is used as an approximation to the set for each of the other 13 cloud types.) The emergent photons at 45 directions in exit zenith angle and azimuth were calculated for four incident zenith angles. These tabular data of bidirectional reflectance coefficients are interpolated for use in the deterministic cloud model. The angular distribution for the photons emerging from diffusion transmission to the non-illuminated surfaces is taken to be diffuse (or Lambertian) in angular distribution.

For evaluation of the photons into and out of the deterministic cloud, the cloud is divided into facets as shown in Figure 2-2. The facets are constructed so as to lie between lines of constant θ and constant ϕ, with more facets of smaller area being concentrated near the regions of maximum curvature in the ellipsoid. In the cloud coordinate system, if a is the semi-major axis lying in the horizontal plane and b is the semi-minor axis, then the division of the azimuthal angle ϕ, where ϕ is measured from the direction of the long axis, is according to the prescription

$$\phi_{6-m} = \frac{\pi}{2} - \psi_m \ , \ \Delta\phi = \Delta\psi \ , \ m = 1,2, \ldots, 5$$

$$\psi_n = \psi_{n-1} + \Delta\psi \left(\frac{b}{a}\right)^{(n-2)\beta} , \ \psi_1 = 0; \ \psi_N = \frac{\pi}{2} , \quad 2 \leq n \leq N = 5$$

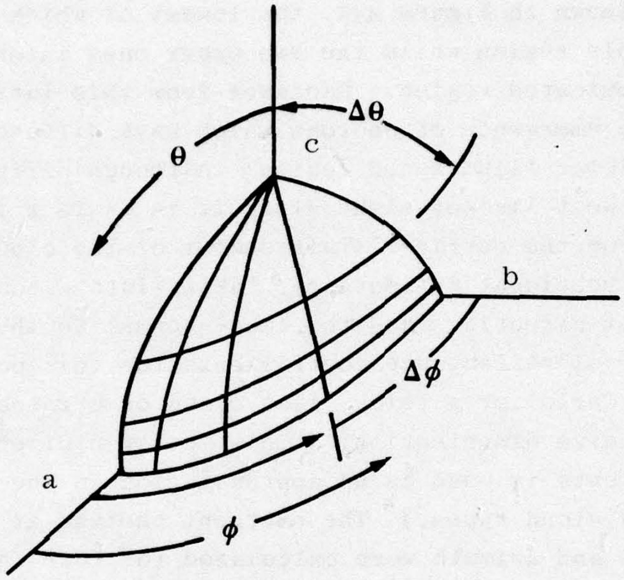

Figure 2-2. Subdivision of ellipsoidal cloud surface into facets.

Given β, this can be solved for $\Delta\phi$, the angular dimension of the first facet, and thus for each of the ϕ_n in a quadrant. Similarly the polar angle θ, measured from the zenith, is divided in a like manner according to the formula

$$\theta_n = \theta_{n-1} + \Delta\theta \left(\frac{c}{a}\right)^{(n-2)\alpha} , \quad \theta_1 = 0; \quad \theta_N = \frac{\pi}{2} , \quad 2 \le n \le N = 5 \quad .$$

The explicit formulas for θ_i and ϕ_i are given in Section 3 with the description of subroutine CLDGEOM. Here α and β are arbitrary exponents chosen to accentuate the grouping of facets at regions of high curvature. A value of $\alpha = \beta = 0.8$ has been used. These facets are then reflected through the principal planes into the other seven octants of the ellipsoid.

The area of facet i,j is given by the expression

$$A_{ij} = \int_{\phi_j}^{\phi_{j+1}} d\phi \int_{\theta_i}^{\theta_{i+1}} d\theta \; r^2 \sin\theta \; (1 + S^2 + T^2)^{\frac{1}{2}}$$

where

$$r^{-2} = \sin^2\theta \left(\frac{\cos^2\phi}{a^2} + \frac{\sin^2\phi}{b^2} \right) + \frac{\cos^2\theta}{c^2}$$

$$S = \sin\theta \; \cos\theta \left[\frac{r^2}{a^2} \cos^2\phi + \frac{r^2}{b^2} \sin^2\phi - \frac{r^2}{c^2} \right]$$

$$T = \sin\theta \; \sin\phi \; \cos\phi \left[- \frac{r^2}{a^2} + \frac{r^2}{b^2} \right] \quad .$$

This integration is performed numerically.

As discussed in Section A-3, the solution for the ellipsoid illuminated by a point source is in the form of the outgoing photon flux (radiant exitance), i.e., watts/kilometer^2, per watt emitted by an isotropic point source. Illumination by the source is converted to ingoing photon flux (irradiance) at each of the illuminated facets by computing

$$J_- = \frac{S \cos \theta_i}{4\pi R^2}$$

for a unit source. Specifically, if $J_+(\vec{r})$ and $J_-(\vec{r})$ are the outward and inward fluxes, respectively, then

$$\left.\begin{aligned} J_+(\vec{r}\,') &= S(\vec{r}\,') - \int_\Sigma J_+(\vec{r})G_+(\vec{r},\vec{r}\,')\,d\sigma(\vec{r}) \\ S(\vec{r}\,') &= -J_-(\vec{r}\,') - \int_\Sigma J_-(\vec{r})G_-(\vec{r},\vec{r}\,')\,d\sigma(\vec{r}) \end{aligned}\right\} \qquad (55)*\&(59)*$$

$$G_{\pm}(\vec{r},\vec{r}\,') = \frac{\hat{n}(\vec{r})}{2\pi}\cdot \text{grad}\ G(\vec{r},\vec{r}\,') \pm \frac{a}{2\pi b}\,G(\vec{r},\vec{r}\,') \qquad (55)$$

$$G(\vec{r},\vec{r}\,') = e^{-KR}/R \qquad (53)$$

$$\text{grad}\ G(\vec{r},\vec{r}\,') \equiv (\nabla G)_{\vec{r}} = G(\vec{r},\vec{r}\,')\,(K+R^{-1})\,\frac{\vec{r}\,'-\vec{r}}{R}$$

$$R = |\vec{r}-\vec{r}\,'|$$

where $\underline{a}$ and b are given in Table A-2. Note that the gradient of $G(\vec{r},\vec{r}\,')$ is evaluated at the inward-flux position $\vec{r}$. In the application of this, we used, in our early work, the approximate solution, $J_{2,+}(\vec{r}\,')$:

$$J_{1,+}(\vec{r}\,')=S(\vec{r}\,')\Big/\left[1 + \int_\Sigma G_+(\vec{r},\vec{r}\,')\,d\sigma(\vec{r})\right] \qquad (60a)*†$$

$$J_{2,+}(\vec{r}\,') = J_{1,+}(\vec{r}\,') - \frac{\int_\Sigma (J_{1,+}(\vec{r})-J_{1,+}(\vec{r}\,'))G_+(\vec{r},\vec{r}\,')d\sigma(\vec{r})}{1+\int_\Sigma G_+(\vec{r},\vec{r}\,')d\sigma(\vec{r})}\ . \qquad (60b)*††$$

In the computation, the integrals are approximated by sums,

$$\xi(\vec{r}\,') = \int_\Sigma f(\vec{r})G_{\pm}(\vec{r},\vec{r}\,')d\sigma \simeq \sum_{j\neq i} f(\vec{r}_j)G_{\pm}(\vec{r}_j,\vec{r}_i)A_j + f(\vec{r}_i)\sqrt{\frac{A_i}{\pi}}\left(-\frac{1}{2R_i} \pm \frac{a}{b}\right)$$

---

*Equation numbers in Appendix A.

†The form of $J_{1,+}$ is obtained by ignoring the last term on the right-hand side of Equation (59) in Appendix A.

††$J_{2,+}$ is obtained by combining Equations (59) and (60a).

where A_i is the area associated with the point $\vec{r}_i$, R_i is the average radius of curvature at that point, and $f(\vec{r})$ represents the multiplier of $G_{\pm}$ in the integrals.

Eventually we found an example of $J_{2,+}$ being negative. Accordingly, after considerable review of the situation, we have settled for using $J_{1,+}$ in the computer code until a better solution is found.

The geometry of the computation is summarized in Figure 2-3. A line-of-sight (LOS) of interest from detector to cloud surface has been established. The quantity of interest is the cloud radiance in the (antiparallel) direction of the LOS at the intersection of the LOS with the cloud. An irradiance-to-radiance transfer coefficient, TCOEF, of dimension sr^{-1}, is provided by the cloud routines which, when multiplied by the normal spectral irradiance at the transfer point on the cloud, gives the required spectral radiance.* Transfer point t_1 in Figure 2-3 is on an element of the surface which is visible to the detector D but is not directly illuminated by the source S. It is thus radiant because of an outward flux of photons supplied by diffusion. Assuming diffuse radiance, the spectral radiance L_λ is given by

$$L_\lambda = \frac{J_{+\lambda}(t_1)}{\pi} \quad ,$$

where $J_{+\lambda}$ is a function of all the irradiances $J_{-\lambda}$'s over the illuminated facets (k), given by

$$J_{-\lambda k} = \frac{S_\lambda}{4\pi R^2_{sk}} \cos\theta_{ik} \quad .$$

The transfer coefficient then is

$$\mathrm{TCOEF}_\lambda = \frac{4\pi R^2_{st_1}}{S_\lambda} L_\lambda \ (sr^{-1}) \quad .$$

Similarly, for points on cloud facets which are both illuminated and visible, such as t_2 in Figure 2-3, the radiance is dominated by directional reflectivity. By definition of bidirectional reflectance coefficient, ρ', the required spectral radiance is

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*In the deterministic model (in contrast with the statistical model) attenuation is not included along the air path. Such attenuation will be computed by the sight-path integration model.

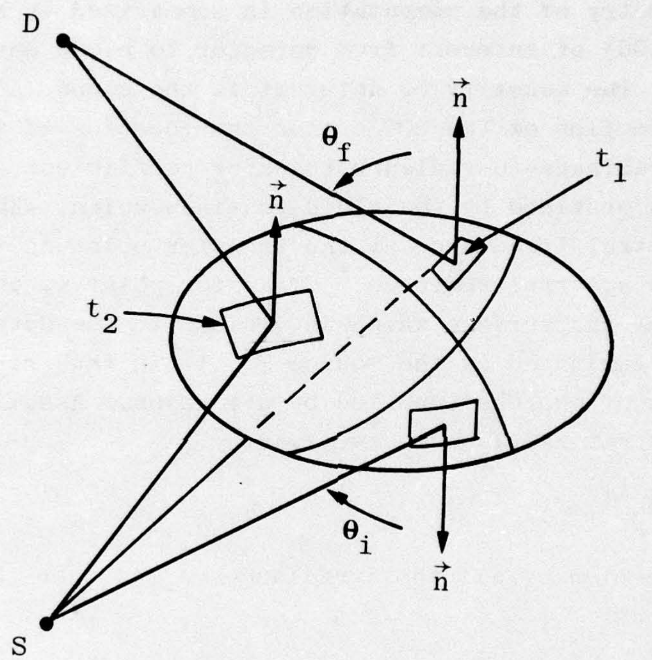

Figure 2-3. Deterministic cloud geometry.

$$L_\lambda = \rho'_\lambda(\theta_i, \theta_f, \phi)\, \frac{S_\lambda \cos\theta_i}{4\pi R^2_{st_2}} \text{ (watt km}^{-2}\text{ sr}^{-1}\mu\text{m}^{-1}) \quad .$$

The transfer coefficient then is again the quantity by which the normal irradiance* at the transfer point must be multiplied to give radiance in the direction of the detector and is given by

$$\text{TCOEF}_\lambda = \frac{4\pi R^2_{st_2}}{S_\lambda} L_\lambda = \rho'_\lambda\,(\theta_i, \theta_f, \phi) \cos\theta_i (\text{sr}^{-1}) \quad .$$

It should be noted that the bidirectional reflectance coefficient is dependent on the angle of incidence, the angle of reflection, and the azimuthal angle ϕ between the incidence and exit planes. This is the quantity which has been separately calculated by Monte Carlo and tabulated for use in the deterministic cloud problem.

The field-of-view of the detector is one of the specified quantities in the problem. The transfer coefficients are properly averaged over this field-of-view to give an average radiance along the line-of-sight. If the field-of-view is less than the facet area projected normal to the line-of-sight, then the facet radiance is the required average radiance. If, however, another facet lies within a distance equal to 0.7 times the square root of the area of the field-of-view, this facet also contributes to the average radiance and its radiance, weighted by the appropriate projected facet area in the field-of-view, is included in the calculation of the average radiance. When part of the field-of-view does not intersect the cloud, i.e., the cloud fills only a portion of the field-of-view, then the contribution of the off-cloud area to the average radiance is zero according to the cloud model. More properly, the line-of-sight integration module may arrange to provide the earth upwelling radiance in this off-cloud fraction.

In addition to the transfer coefficient which gives radiance resulting from the source, the cloud as an emitter of radiation must be considered. This self-emission radiance is calculated by assuming the cloud to be at the ambient atmosphere temperature at the altitude at which the LOS intersects the cloud and to emit a blackbody spectrum of that temperature with an appropriate emissivity in the direction of the

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*See footnote on page 22.

line-of-sight. The directional emissivity is taken to be one minus the directional reflectance, $\rho_{d\lambda}$. The directional reflectance is computed by integrating the bidirectional reflectance coefficient, ρ'_λ, over the 2π solid angle, holding constant the incident direction equal to the angle between the LOS and the normal to the surface. That is, the emission spectral radiance at the transfer point in the direction of the detector, $L_{e\lambda}$, is given by

$$L_{e\lambda} = (1-\rho_{d\lambda}) \frac{c}{4\pi} c_1 \lambda^{-5} \left(e^{c_2/\lambda T} - 1\right)^{-1} \quad (\text{watt}/(\text{km}^2 \text{ sr } \mu\text{m}))$$

where

$$c_1 = 8\pi ch, \; c_2 = ch/k, \text{ and}$$

$$\rho_{d\lambda}(\theta_i) = \int_{2\pi} \rho'_\lambda (\theta_i, \theta_f, \phi) \cos\theta_f d\Omega_f \; .$$

Since this radiance is independent of sources in the problem, it is not given as a transfer coefficient but is calculated as a spectral radiance ($\text{watt}/(\text{km}^2 \text{ sr } \mu\text{m})$). Note that the emissivity of each of the 14 cloud types is taken to be that computed for cloud-type 4.

If the problem being examined is a daytime problem so that the sun also illuminates the cloud, a third source of cloud radiance exists. The solar reflected radiance is calculated exactly as though the sun were another point source and the transfer coefficient for that geometry is the output.

2-2 STATISTICAL CLOUD MODEL

The ROSCOE-IR statistical cloud model is based on the cloud descriptions and cloud occurrence data bank of Fowler et al. (Reference 1). The clouds are described as horizontal plane parallel slabs with a base altitude and a top altitude given for each cloud type, together with water-droplet average densities and droplet-distribution average radii. The occurrence data provide the probability that each such cloud type will occur singly or in multiple layers with other types. The data are further divided into coverage categories ranging

from clear (cover category 1) to full cloud cover (cover category 5) approximately by quarters (compare definitions of CCOVER in Section 4-2), so that the likelihood of a LOS being cloudy or cloud-free may be determined.

The data base is divided into the 30 geographic regions shown in Figure 2-4. Two regions of interest were selected. One of these is region 11 of the global data bank which is a temperate continental region and characterizes the northeast United States and western Europe. The second region is region 4 which is a tropical maritime region and includes, for example, the Hawaiian Islands. For each region, five subsets of the total data base have been selected for use in ROSCOE to provide a total of 10 user options. They are, for each region, the annual average, the winter day average, the winter night average, the summer day average, and the summer night average. For each of these options there is available the probability of occurrence of each of the 14 cloud types singly or in multiple layers, for each of the four cloud-coverage categories, and a probability for cloudless skies. An eleventh option permits the user to construct his own cloud-type occurrence probability table, it being required only that he utilize the same 14 cloud types for which physical descriptions exist. This option permits the user to examine the effect of any one of the cloud types and permits construction of cloud scenes characteristic of the information contained in weather reports or other cloud descriptions.

In the statistical cloud data base there are seven types of low-altitude clouds, three middle types, and four high types. Allowing only one cloud type in each altitude regime, the possible configurations include clear, the 14 types alone as a single layer, 61 combinations of two types in double layers, and 84 triple-layer combinations of three types. Thus 160 configurations are possible, neglecting the possibility of considering the four fractional cloud-coverage categories as the basis of a further factor of four.

This last consideration is avoided by treating only two aspects of each configuration, namely the possibilities of a cloud-free line-of-sight (CFLOS) along the ROSCOE user's LOS and of a LOS obscured by clouds. In the latter case, the clouds are assumed to be extensive in horizontal dimension so that the radiation transfer is the same as for plane parallel

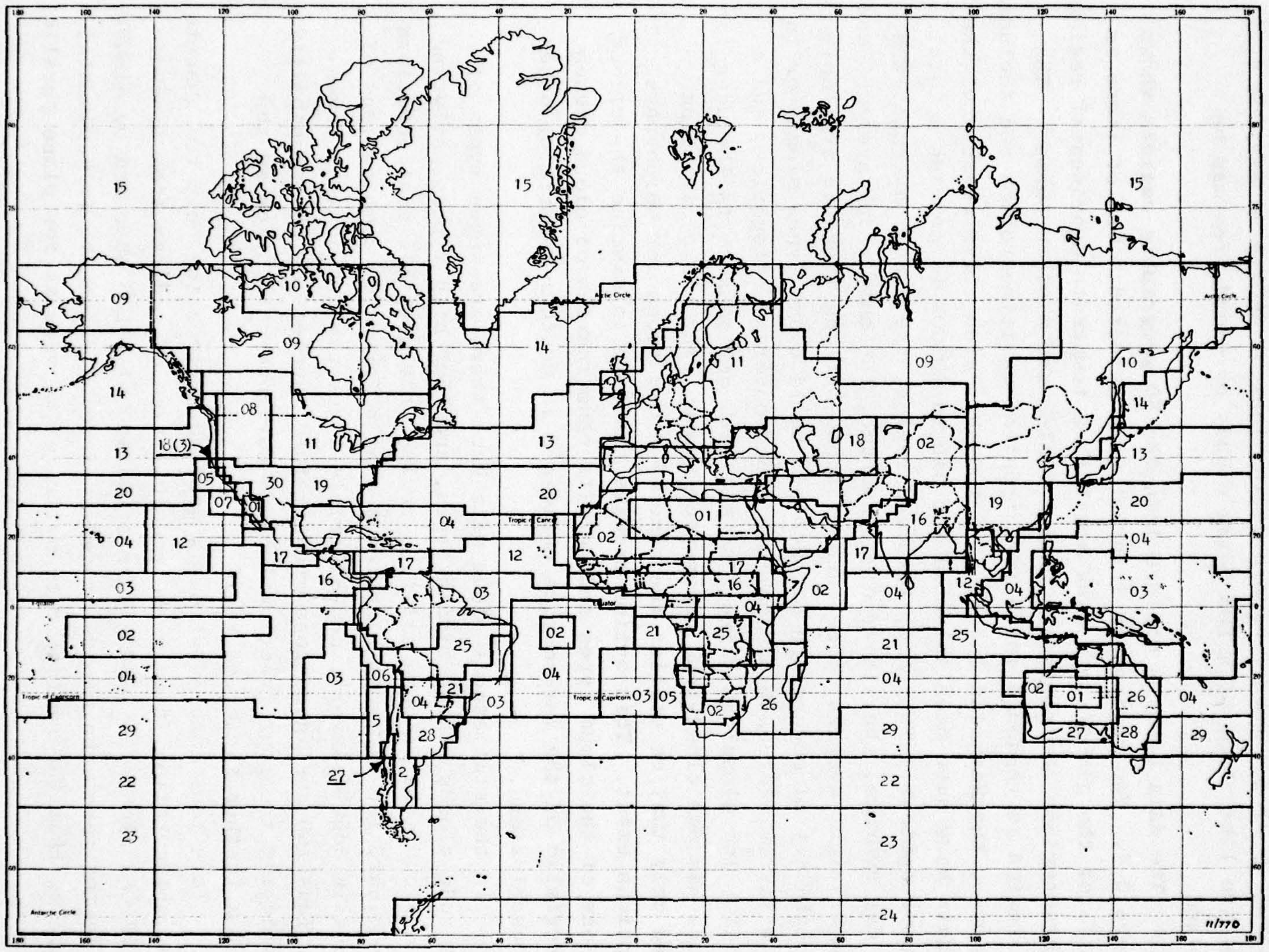


Figure 2-4. Geographic regions of the NASA worldwide cloud data bank.

layers of infinite extent. This is consistent physically with most fractional coverage cases, i.e., the cloud patches are large and the gaps are large. Thus only 160 possible configurations must be addressed.

For the ROSCOE-IR statistical cloud model it was required to provide spectral radiance quantities along the selected line-of-sight, namely radiance quantities arising from NUDET sources, solar reflection, and cloud emission. In order to retain an interface with the main program similar to that of the deterministic cloud model, the effects of NUDET and solar sources were to be returned separately as transfer coefficients, with units of sr^{-1}, and the emission was to be returned separately as a spectral radiance in units of watt km^{-2} sr^{-1} μm^{-1}.

Since the number of possible configurations of clouds is so large, it was decided not to transfer from the main program to the statistical cloud routine and back again for each possible cloud configuration but rather to loop through the configurations, each having its own probability, within the cloud routine and to return to the main program the probability distribution of radiance results.

The probability distribution is the result of the fact that each of the 159 cloudy configuration cases has a probability, or frequency weight, which can be determined from the ratio of the frequency of observed cases of this configuration to the total number of observations. These frequencies are in the data base.

The weights of each configuration are adjusted to take account of the probability of a CFLOS. The weight W(i) for the LOS intersecting the i-th cloudy configuration is thus

$$W(i) = \sum_{cc=2}^{5} W(i)_{r,cc} \, [1-CFLOS_{cc}(\theta)]$$

where $W(i)_{r,cc}$ is the raw weight of the i-th configuration by type, layers, and coverage-category cc and $CFLOS_{cc}(\theta)$ is the probability for a CFLOS at the zenith angle θ and fractional coverage index cc. The CFLOS probabilities are derived from Lund's tables of CFLOS probability for all cloud types combined as a function of zenith angle and fractional coverage (Reference 3). The weight assigned to the clear line-of-sight is then

$$W(\text{clear}) = P(cc=1) + \sum_{i=1}^{159} [1-W(i)]$$

where P(cc=1) is the weight of the clear cloud-coverage category (no clouds) and the sum represents the gap contributions from the partial coverage configurations. A more detailed treatment of these equations is given in the discussion of subroutine CLDWT in Section 3-2.

The statistical cloud routines then perform the appropriate calculation of radiation transmission for 159 configurations of cloud cover and for clear conditions and assign to each the probability weights, W(160) = W(clear) being the clear line-of-sight weight. The result is a distribution of 160 values of the radiance-related quantity calculated, each with its weight, or probability. The distribution is summed to provide an integral or cumulative distribution and radiance-related values from this cumulative distribution and provided as output at designated optional fractile values of probability provided as input in the call. W(clear), known in the code as PCFLOS, is also provided as an output, to be used as an approximation to the probability of a CFLOS to a NUDET source within the detector's field-of-view and below 12-km altitude.

The radiance-related quantities follow the same system as those of the deterministic cloud model, except that distributions rather than single values are the output. For NUDET sources and for the sun, the output is a distribution in transfer coefficients which, when multiplied by the (unattenuated) spectral irradiance at the transfer point from the source, results in a distribution of spectral radiances along the line-of-sight. The required spectral radiance L_λ and the transfer coefficient are related by the expressions

$$L_\lambda = \mathrm{TCOEF}_\lambda \cdot \begin{cases} \dfrac{S_\lambda}{4\pi R_{st}^2} & \text{(source)} \\[2ex] E_\lambda & \text{(sun)} \end{cases}$$

where S_λ is the isotropic point-source spectral power, R_{st} is the source-to-transfer-point distance, and E_λ is the solar irradiance. The cloud thermal emission output, however, is an actual radiance in units of watt $km^{-2}\mu m^{-1}sr^{-1}$ rather than a coefficient, because the thermal emittance is not related to NUDET or solar source strengths but depends solely on cloud temperature and emission properties. Again, as for the deterministic case, the NUDET, solar, and thermal emission outputs are provided separately.

Figure 2-5 is indicative of the geometry of the statistical cloud problem. One or more cloud layers for each of the 159 configurations will lie somewhere between 0.15-kilometer and 12-kilometer altitude. These are the base of the stratus and the top of the cumulonimbus-3 cloud models, respectively. In addition, a point source will be located somewhere in the figure such as at S1, S2, or S3. The source location will be either below the base of the lowest cloud, somewhere in the region occupied by one or more cloud types, or above the top of the highest cloud. A method has been developed for treating each of these cases. As a matter of fact, during the progression upward of a fireball from a low-altitude explosion, the source will progressively occupy each sort of location relative to the cloud region.

The statistical cloud program calculates the irradiance-to-radiance transfer coefficient along the reverse LOS at a transfer point, tp, which is chosen to be the intersection of the LOS with the 12-kilometer altitude plane, because all cloud tops lie at or below this point. By treating the atmospheric transmission problem in the cloud region within the cloud subroutines, as discussed later, it is possible to avoid having the main program integrate along the LOS to each of the 159 cloud-top altitudes in the entire statistical problem.

In addition to NUDET sources the sun as a radiation source is also indicated in Figure 2-5. For each of the 159 cloud configurations the sun illuminates the highest cloud top of the configuration and by reflectance contributes to the radiance along the LOS. The transfer coefficient corresponding to this solar reflected radiance is again a distribution of 160 points and is provided as a separate output distribution from that of a NUDET source. Note, however, in the 160-point distribution, there are only 10 different values (nine for clouds, one for Earth) because (a) there are only nine different cloud-top altitudes

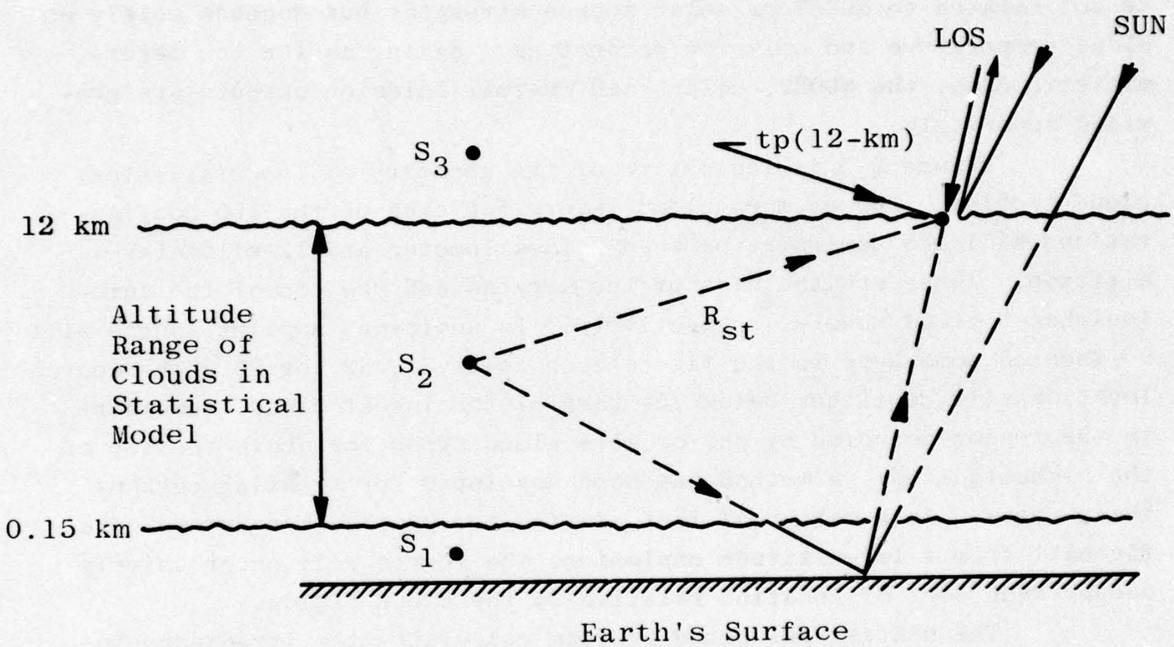


Figure 2-5. Statistical cloud geometry.

(cf. Table 2-1) and (b) the bidirectional reflectance of any cloud is assumed to be approximated by that for cloud-type 4 (stratocumulous).

In addition to the LOS intersecting cloud tops in the 159 cloud configurations, there is the probability of a CFLOS to the Earth's surface, which acts as a solar reflector and as an emitter. The surface may be sunlit or not, the probabilities depending on the probability of a CFLOS to the surface point from the sun. The contribution of the surface reflectance is weighted by the product probability of a two-leg CFLOS.

Finally, as in the case of the deterministic clouds, the statistical cloud tops are emitters which contribute to the radiance along the LOS. The cloud top for each configuration is treated as a blackbody-spectrum emitter at the temperature of the cloud top and with directional emissivity equal to $(1-\rho_d)$ as in the deterministic case. (The directional emissivity computed for cloud-type 4 (stratocumulous) is used for all cloud types.) This emission radiance distribution is again carried separately from the NUDET source and the solar distributions. The surface is again the 160th point in this distribution. As in the solar reflectance case, there are only 10 different values in the 160-point distribution.

A summary guide to the distributions available from the statistical cloud model is given in Table 2-2.

Figure 2-6 is a schematic of one of the calculations. A point source lies below a plane parallel cloud. By the solution of the diffusion problem in cylindrical geometry, described in Section A-2.1.3, the spectral flux leaving the cloud top is calculated and has a bell-shaped radial distribution as indicated in (a). The outgoing flux (radiant exitance or emittance) at the cloud top, J_+, is given by a sum of weighted Bessel functions (Equation (30a), with Q = S/2) and the radiance, L, is just this flux divided by π, since the angular distribution is taken to be diffuse. The radiance at the point where the LOS intersects the cloud top is calculated and divided by the cloud-free normal irradiance at the transfer point, TP, to give a transfer coefficient with units of sr^{-1} as in the deterministic case. That is,

$$TCOEF_\lambda = \frac{4\pi R_{st}^2 L_\lambda \tau_\lambda}{S_\lambda}$$

Table 2-2. Guide to distributions from the statistical cloud model.

IDX	LOS Terminates On	Thermal Emission, Radiance $W/(km^2\ sr\ \mu m)$	Solar Source Transfer Coeff., sr^{-1}	Artificial Source Transfer Coeff., sr^{-1}
1 to 159	Clouds	a	c	e
160	Earth	b	d	d

[a]Each emission in the set of 159 is from the top of the uppermost cloud layer and is attenuated along the path to the transfer point at 12-km altitude. There are nine distinct values among the 159 values of such radiance corresponding to the nine different cloud-top altitudes.

[b]The emission is from the Earth's surface (the nature of which can be specified) and is attenuated along the path to the transfer point at 12-km altitude.

[c]Each of the transfer coefficients in the set of 159 corresponds to the bidirectional reflectance of the uppermost cloud layer for the incident- and reflected-photon geometry and includes air transmittance along those portions of the incoming and reflected paths below 12-km altitude. The nine distinct values among the 159 values of such transfer coefficients correspond to the nine different cloud-top altitudes.

[d]The transfer coefficient corresponds to the bidirectional reflectance of the Earth's surface for the incident- and reflected-photon geometry and includes air transmittance along the incoming- and reflected-photon paths below 12-km altitude. The weight for this case includes the (product) probability of a two-leg CFLOS instead of a one-leg CFLOS as for the thermal emission case.

[e]A given transfer coefficient may correspond to either (a) transmittance through cloud layers between the source and the transfer point or (b) bidirectional reflectance from the uppermost cloud layer below the source. Thus the distribution will include a combination of the above two types of transfer coefficients for a source above the lowest cloud-top altitude (1.0 km) and below the highest cloud-top altitude (12.0 km). For each transfer coefficient one includes air transmittance along those portions of (nominal) paths below 12-km altitude.

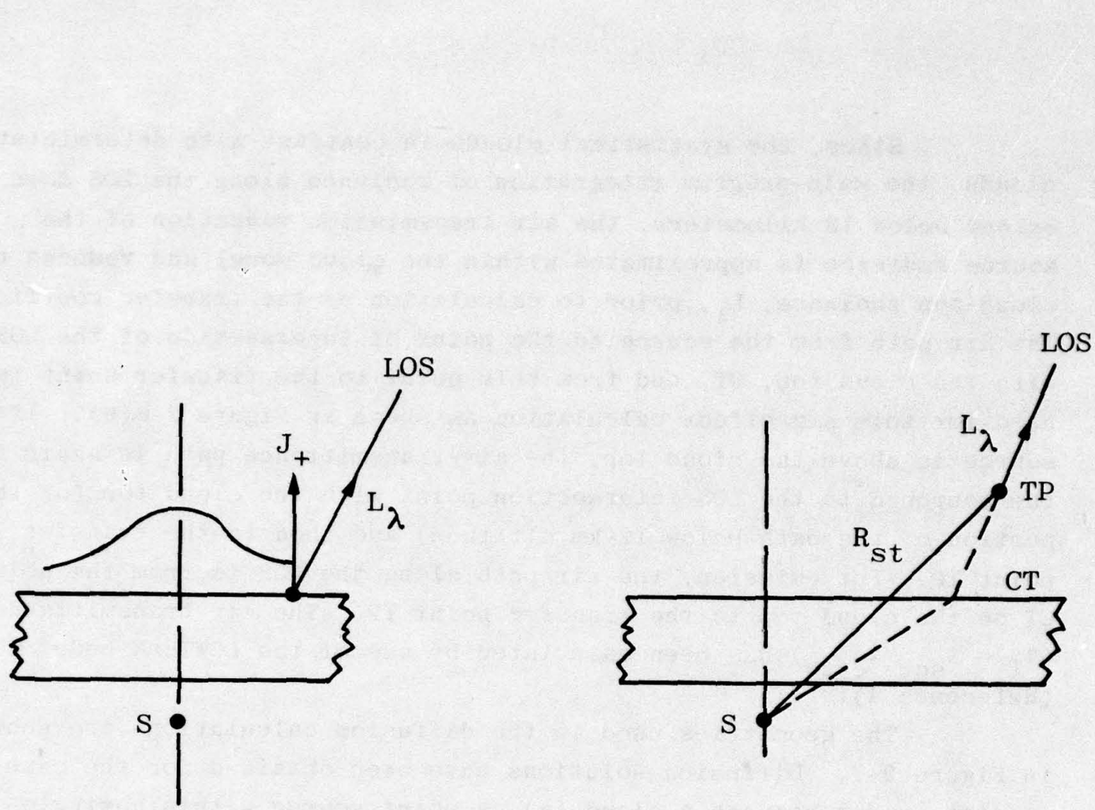


Figure 2-6. Typical statistical cloud geometry. (a) shows the bell-shaped radial distribution of flux, J_+, leaving the cloud top and (b) shows the source-to-transfer-point distance R_{st} and the air transmittance path S-CT-TP.

Since, for statistical clouds in contrast with deterministic clouds, the main-program integration of radiance along the LOS does not extend below 12 kilometers, the air transmission reduction of the source radiance is approximated within the cloud model and reduces the cloud-top radiance, L_λ, prior to calculation of the transfer coefficient. The air path from the source to the point of intersection of the LOS with the cloud top, CT, and from this point to the transfer point is used for this air-effect calculation as shown in Figure 2-6(b). If the source is above the cloud top, the air-transmittance path is again from the source S to the LOS intersection point with the cloud top (or that portion of the path below 12-km altitude) and then to the transfer point TP. For emission, the air path along the LOS is from the point CT on the cloud top to the transfer point TP. The air transmittance ($\tau_\lambda = \tau_{sct}\ \tau_{cttp}$) has been calculated by use of the LOWTRAN code (Reference 4).

The geometries used in the diffusion calculations are shown in Figure 2-7. Diffusion solutions have been obtained for the case of a point source beneath a cloud (a), a point source within a single-layer cloud (b), and for a point source at or below the base of a multi-layered configuration of any number of layers (c). These three cases handle the necessary configurations with two exceptions. First, the cloud-type descriptions do not necessarily result in the base of an upper cloud coinciding with the top of a lower cloud so that gaps or overlaps exist between multiple layers. When this occurs the base of the higher layer is adjusted to coincide with the top of the layer below, the optical thickness of the upper layer being retained by adjustment of the particle number density. In this manner a continuous multi-layer medium is created which is compatible with the available diffusion solutions. Second, when the source lies within a cloud member of a multiple layer as shown in Figure 2-7(d), the cloud region below the source is neglected (truncated) so that the problem is reduced to that of Figure 2-7(c) with the source on the bottom surface. (The two adjustments are not commutative. In the code, we have implemented the second adjustment before the first.) The truncation modification is expected to cause about a 10% reduction in the cloud-top radiance, this being the approximate magnitude of the albedo* for these

*See function RHOEPS for a tabulation at 10 wavelengths of the hemispherical-directional reflectance, or equivalently, directional-hemispherical reflectance.

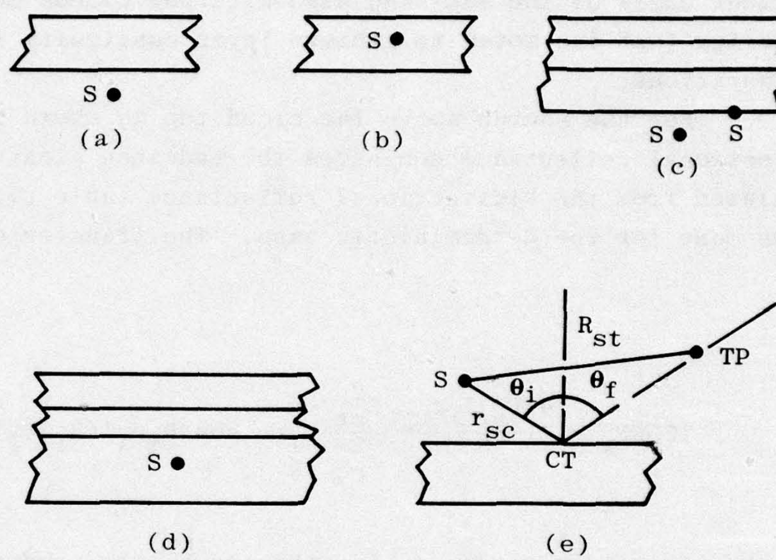


Figure 2-7. Diffusion and reflectance geometries for statistical clouds. Diffusion solutions have been obtained for Cases (a), (b), and (c). Case (d) is treated approximately by truncating the cloud region below the source, thereby converting it to Case (c) with source on surface. The solution for the transmitted photon flux is given by Equation (30a) for Case (a), by Equations (26b) and (40a) for Case (b), and by Equations (69) and (70) for Case (c). Note that Cases (a) and (b) become identical for the source on the surface (h=0). In this regard, one can verify that for h=0, Equation (40a) becomes identical to Equation (29a) provided Q in Equation (29a) is set equal to one-half of the isotropic source strength, S. In Equation (40a), S is tacitly unity.

clouds in the two- to five-micron region. A reflecting layer of albedo ω below the source increases the cloud-top radiance by a factor of about $1/(1-\omega)$, as shown at the end of Appendix D.

Figure 2-8 shows the assumed altitude range of each of the 14 cloud types for single-layer configurations. The dashed lines at the lower edges of the mid- and high-altitude clouds depict the boundaries that are moved to achieve layer contiguity in multilayer configurations.

For the source above the cloud top as shown in Figure 2-7(e), bidirectional reflectance dominates the radiance along the LOS and is calculated from the bidirectional reflectance table (Function CLDBDR) as was done for the deterministic case. The transfer coefficient is then

$$\mathrm{TCOEF}_\lambda = \frac{4\pi R_{st}^2 L_\lambda \tau_\lambda}{S} = \frac{R_{st}^2}{r_{sc}^2} \tau_i \tau_r \cos \theta_i \rho_\lambda'(\theta_i, \theta_f, \phi) \quad .$$

Here the air transmittance τ_λ is taken to be the product of the transmittances τ_i and τ_r along those portions of the incoming and reflected paths below 12-km altitude.

Examples of statistical cases are given in Section 4 and show both the radial distribution of radiance across the cloud tops and examples of the probabilistic distributions in radiance arising from the many possible cloud configurations.

Through use of the statistical cloud model the user may obtain three separate distributions for spectral radiance from NUDET sources, from the solar source, and from thermal emission backgrounds. It is rather obvious but perhaps worthy of note that these distribution data are more complex quantities than would be the three simple radiance values from a completely deterministic case. The three simple radiances, for example, can be added to give the total radiance which would be observed by a sensor. They can be divided to give ratios of signal-to-noise, signal-to-solar background, etc. Such quantities are often important measures of sensor effectiveness.

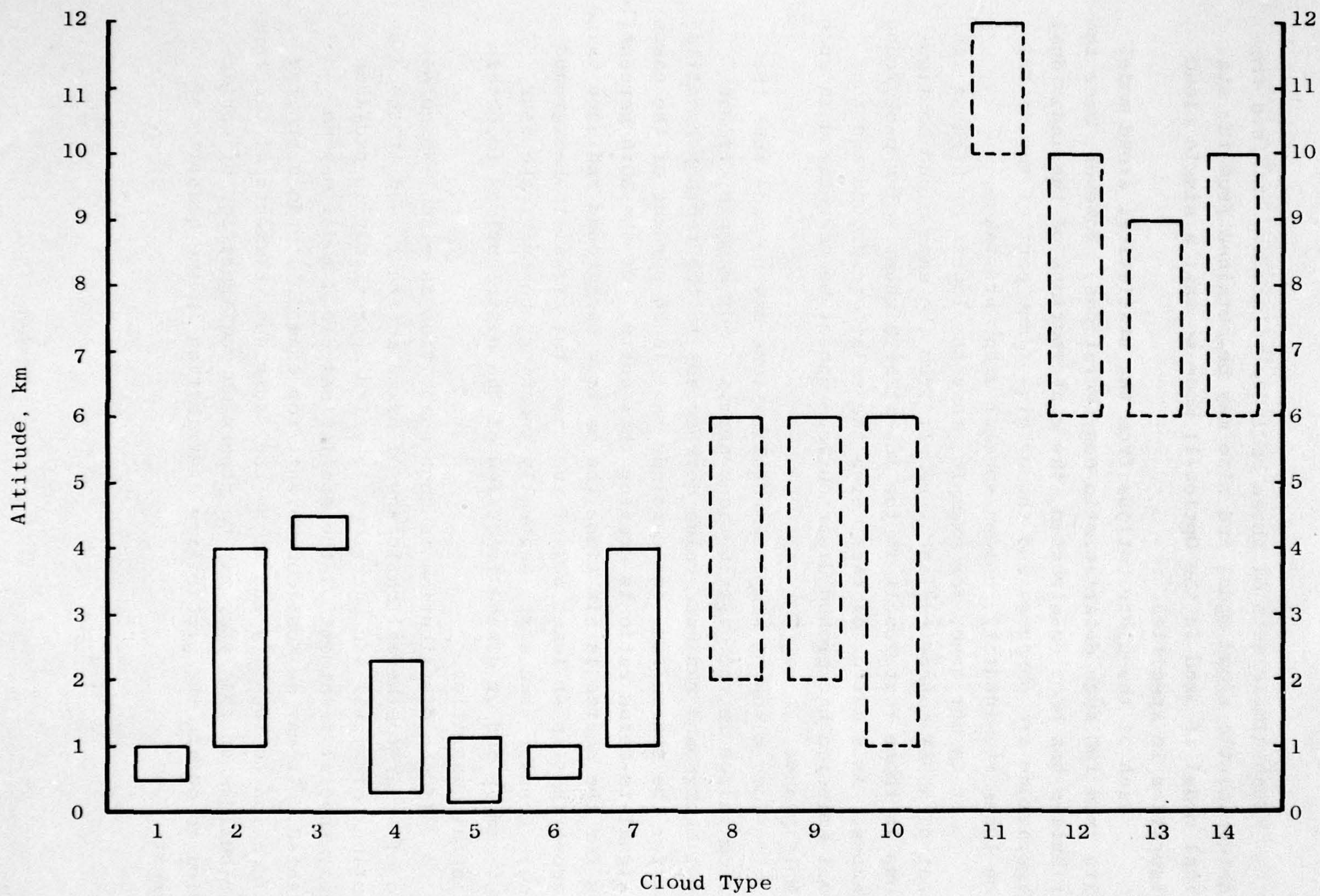


Figure 2-8. Altitude ranges of single-layer cloud types.

Such simple sets of three radiance values are obtained from the deterministic cloud model and also may be obtained from the statistical model if used in the Option-11 mode so that a single cloud configuration is specified.

Each of the distributions from the statistical cloud model results from 160 such deterministic configurations. However, once the distribution has been constructed, the contributions of the individual configurations are obscured and the origin of any part of the distribution loses its identity, unless special steps are taken.

It is not true, for example, that the lowest or highest ten percent of NUDET source radiances result from the same cloud configurations as those that result in the lowest or highest solar background radiances. As a matter of fact, even the solar background and the thermal emission background distributions cannot be correlated in such a simple manner.

Some kinds of simple generalizations may be made when the radiance values in the distributions permit. For example, if the highest background radiance value corresponds to the tenth percentile value for the source, one can conclude that in 90 percent of the cases the signal-to-noise ratio is greater than unity. If the 50th percentile value for the source is six times the maximum background radiance value, one knows that in at least 50% of the cases the signal-to-background ratio is greater than six. Generally speaking, however, the user cannot simply add or divide fractiles of the distributions to obtain meaningful quantities.

If the distribution in such quantities as signal-to-noise ratio of solar-to-thermal ratio are of prime interest, and if the distributions of signal and background overlap appreciably in radiance values, special treatment of the statistical cloud model may be warranted. It may be most convenient, for example, to do a program modification to identify and store the individual elements of the three distributions so that they may be processed configuration by configuration to obtain the probability distribution in the quantity of interest.

SECTION 3
COMPUTER PROGRAM DESCRIPTION

3-1 INTRODUCTION

The main (or driver) program ROSCOER is intended to demonstrate the utility of the ROSCOE-IR cloud computation procedure and to facilitate integration of the subroutines into ROSCOE-IR. All requirements of the computational procedure are met in ROSCOER to provide a stand-alone code and to provide a guide to the intended use of the subroutines. All overall program flow is illustrated in Figure 3-1.

Data provided by ROSCOE-IR (such as source, detector, and sun location) are read by the driver program ROSCOER or are entered via data statements. Calls to the deterministic and statistical cloud submodules are illustrated via ROSCOER. There is no preferential looping on lines-of-sight, wavelength, or cloud number. The calling program, ROSCOER, simply demonstrates how the code can be used. The deterministic check case (Problem 6 in Section 4) loops over the 64 possible lines-of-sight* at the second wavelength in the wavelength table, i.e., λ = 2.5 μm. A check case for the statistical cloud submodule (Problems 1 to 4, Section 4) loops over as many as 161 lines-of-sight at one-quarter kilometer intervals from the source normal to the lines-of-sight. The transfer coefficient is integrated with proper conversions to give a total transmission

Several parameters are initialized by statements in the main program only as a means of checking the code calculations and demonstrating its utility. The user will necessarily obtain this information by a replacement of this main program. A call to subroutine CLOUDO obtains data that are required only by the cloud package and establishes the mode to be that of either a statistical cloud data base or a set of deterministic clouds. Deterministic cloud properties are still obtained from the preprogrammed data base; however, sizes and shapes, within the ellipsoidal constraint, and locations are to be provided by the user.

*The number of lines-of-sight returned by subroutine LOS has been reduced from a maximum of 64 to a maximum of 16 by incrementing the facet-center indexes by 2's, a procedure that appears to be adequate.

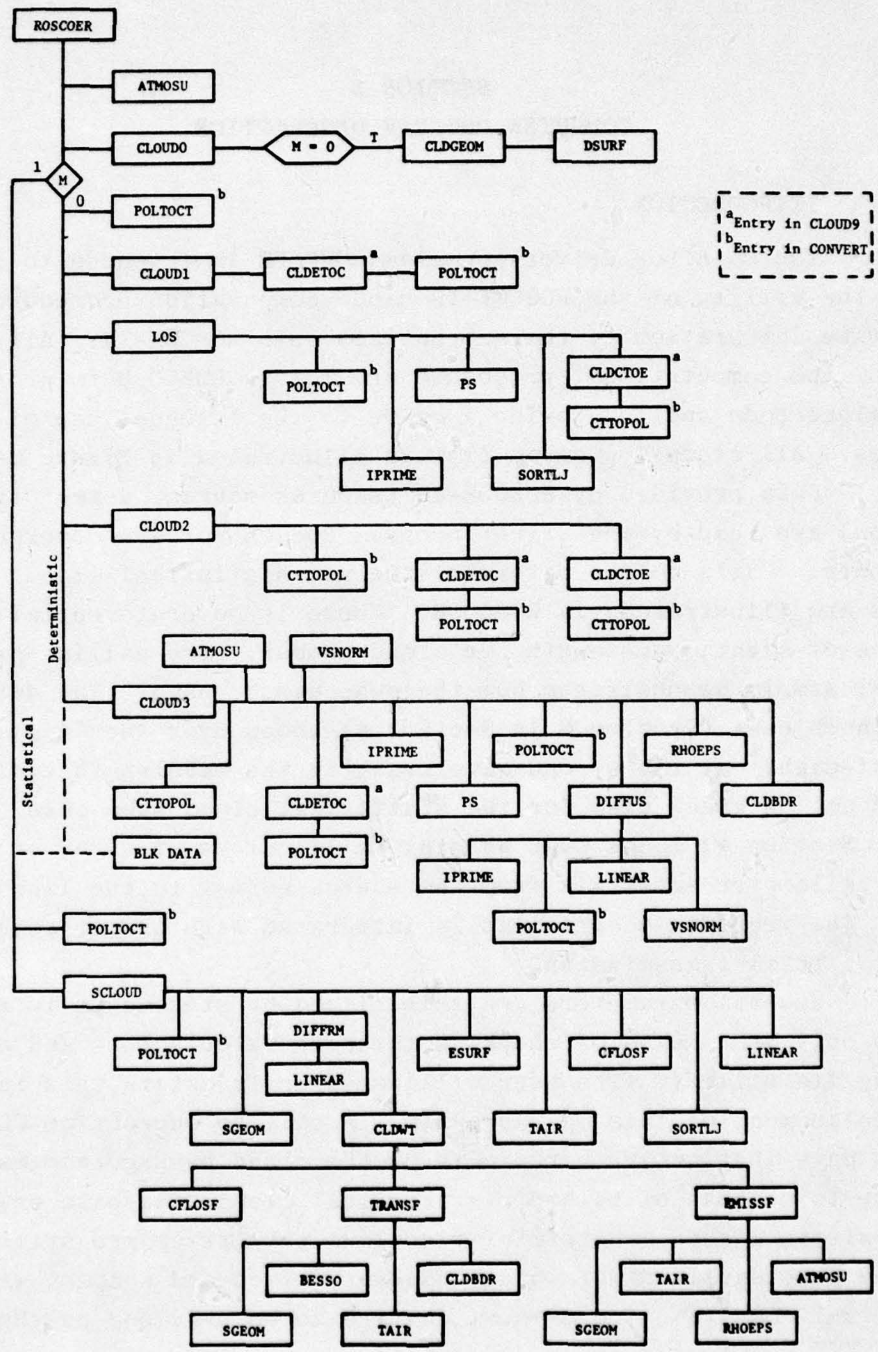


Figure 3-1. Flow chart of ROSCOE-IR cloud module.

The transfer coefficients for the calculations will, of course, be multiplied by a source irradiance to obtain a radiance in the direction of the detector at the transfer altitude of 12 kilometers (for statistical clouds). This coefficient, as well as the emission, has included in it the atmospheric transmission, in both directions, if appropriate, from the 1962 U.S. Standard Atmosphere as calculated from LOWTRAN 3 (Reference 4). No atmospheric attenuation is included in the deterministic case because it will be computed by the line-of-sight integration module in ROSCOE-IR.

Parameters such as lines-of-sight and wavelength are also user defined. A table of wavelengths is provided in common CDDATA at which cross sections are tabulated. This list provides a set of possible wavelengths to check out the code and to make specific calculations. The only restriction on wavelength is that it be between two and five microns.

A line-of-sight must be provided to both the deterministic and statistical subroutines. Possible lines-of-sight are provided for deterministic clouds by a call to subroutine LOS. These are, in turn, available in common LOS. A maximum of 64 lines-of-sight are returned. This table is terminated by zeros in the altitude array HLOS. Any or all of these lines-of-sight are appropriate for subsequent deterministic calculations.

Since a statistical cloud is infinite in lateral extent, there is no mechanism to relate the detector line-of-sight to the cloud. One usually has a particular scenario which directs which way the detector is looking and it is this consideration which gives rise to the input for statistical clouds. There is, however, little reason to make transmission calculations for horizontal distances in excess of five times the source to cloud-top distance. This situation may occur in statistical cases where the transmission is negligible; however, the code doesn't bother to eliminate the calculation.

The routines called to get an answer are CLOUD3 (UL,VL,WL,K, ALAM,TCOEF,EMISS,SINCLD) for deterministic clouds and SCLOUD(ALAM,UL, VL,WL,ISUN) for statistical clouds, where UL,VL,WL are the direction cosines of the LOS, ALAM is the wavelength in microns, TCOEF is the irradiance-to-radiance transfer coefficient at the intersection point of the LOS and cloud-K, EMISS is the thermal emission from the cloud

at the intersection point, and ISUN is a flag to distinguish between an artificial source and the sun. Common PTE variables must be initialized and utilized as follows:

(Input)

P1,P2,P3,P4 - four probability levels (fractiles) for which transfer coefficients and thermal emission are required.

(Output)

T1,T2,T3,T4 - four transfer coefficients corresponding to the P1,P2,P3,P4 above.

E1,E2,E3,E4 - thermal emission corresponding to P1, P2,P3,P4 above.

S1,S2,S3,S4 - four transfer coefficients corresponding to P1,P2,P3,P4 above for the sun as a source.

PCFLOS - probability of the detector seeing the artificial source, either with or without clouds being present, provided the source is within the field-of-view.

3-2 DESCRIPTION OF SUBROUTINES

A summary of the information necessary to execute each of the subroutines is provided in this section. Some of the subroutines are documented to a greater extent than others as the use of many is self-evident.

3-2.1 Program ROSCOER

The driver program ROSCOER is used to provide test cases for the deterministic and statistical cloud submodules. Data are read for the locations of the source and detector. A call to CLOUD0 reads the data which are required by the cloud module. Branching is directed by a mode flag to the submodules.

The deterministic mode is illustrated by a call to subroutine LOS and subsequent calls to subroutine CLOUD3 for the lines-of-sight determined by LOS. The statistical mode is illustrated by a series of lines-of-sight providing a function which is subsequently integrated across the cloud top to give total transmission.

3-2.2 Subroutine ATMOSU(JJ,ZH)

This subroutine, a dummy routine for the real one (see the ROSCOE Manual, Volume 14a-1), provides the atmospheric density (g/cm^3) and temperature (degrees K) as a function of altitude (km). The common ATMOUP is utilized with the fifth and sixth locations being the density and temperature. The calling sequence is (2,ZH), ZH being the altitude. The value of 2 for JJ denotes an operational call, allowed after ATMOSU has been initialized earlier with JJ=1. The density and temperature are provided by simple expressions:

```
RHO = 1.225E-3 * EXP(-ZH/9.)
  T = 288. -ZH * 6.5
```

3-2.3 Function BESSO(X)

This routine provides the zero-order cylindrical Bessel function per formulas 9.4.1 and 9.4.3 in the NBS Handbook (Reference 5).

3-2.4 Block Data

This BLOCK DATA set contains the extinction (SIGT(10,14)) and scattering (SIGS(10,14)) cross-sections and the average cosine of the scattering angle (XMUBAR(10,14)) for the 14 cloud types. Units for the cross sections are square microns; cloud droplet number density is in reciprocal cm^3. The code uses km^{-1} as macroscopic cross-section units with the conversion from microscopic cross-sections being

$$\sigma_x(km^{-1}) = \sigma_x(\mu m^2) \times N(cm^{-3}) \times \frac{10^{-8} cm^2}{\mu m^2} \times 10^5 \frac{cm}{km} .$$

SIGT, SIGS, and XMUBAR are tabulated at 10 wavelengths from 2 to 5 microns. The entries were calculated by Mie theory[a] using cloud properties from Fowler (Reference 1) and given in Table 2-1.

Also tabulated are cloud coverage, CCOVER(5,11), and frequency, CFREQ(17,4,11), data for the statistical module.

---

[a]See the comment at the end of Section 3-2.16 for an exception to this statement.

CCOVER(1,K) is frequency of clear sky
(2,K) is frequency of cloud-coverage category 2
(3,K) is frequency of cloud-coverage category 3
(4,K) is frequency of cloud-coverage category 4
(5,K) is frequency of cloud-coverage category 5

where K is the model (i.e., time, region) discussed in Section 2-2.

CFREQ(I,J,K), I=1,17; J=1,4: K=1,11

CFREQ(1,J,K) is frequency of Cu1
(2,J,K) is frequency of Cu2
(3,J,K) is frequency of Cu3
(4,J,K) is frequency of Sc
(5,J,K) is frequency of St
(6,J,K) is frequency of Cb1
(7,J,K) is frequency of Ns
(8,J,K) is frequency of Ac
(9,J,K) is frequency of As1
(10,J,K) is frequency of Cb2
(11,J,K) is frequency of Cb3
(12,J,K) is frequency of As2
(13,J,K) is frequency of Ci
(14,J,K) is frequency of Cs

$$\text{where} \sum_{I=1}^{14} \text{CFREQ}(I,J,K) = 1$$

CFREQ(15,J,K) is frequency of 1 layer
(16,J,K) is frequency of 2 layers
(17,J,K) is frequency of 3 layers

$$\text{where} \sum_{I=15}^{17} \text{CFREQ}(I,J,K) = 1$$

J is the cloud-coverage index and K is the model number.

3-2.5 Function CFLOSF(ICC,ANGLE)

This function obtains a value for the probability of a cloud-free line-of-sight from a table by Lund and Shanklin (Reference 3). The array is tabulated for cloud coverage (in 10ths) and for zenith angles in 10-degree increments from 0 to 90°. The table is for all cloud types combined.

The calling sequence requires the cloud-coverage index ICC to be an integer in 10ths and the angle in degrees.

INPUTS:

ICC-1 - cloud coverage (10ths)

ANGLE - zenith angle in degrees

OUTPUT:

CFLOSF - probability of a cloud-free line-of-sight at a given zenith angle for the requested cloud-coverage index ICC

Cloud coverages reported in tenths were grouped into five caregories by the authors of Reference 1 (p.3):

Coverage category 1	0 tenths
Coverage category 2	1,2,3 tenths
Coverage category 3	4,5 tenths
Coverage category 4	6,7,8,9 tenths
Coverage category 5	10 tenths

In our cloud model the decimal cloud-coverage fractions of 0.0, 0.3, 0.5, 0.8, and 1.0 are assigned to the cloud-coverage categories 1,2,3,4 and 5, respectively.

3-2.6 Function CLDBDR (CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD)

This function contains tables of bidirectional reflectances for a stratocumulus cloud. The data are tabulated in forty-five equal solid angle bins at 10 wavelengths from 2 to 5 microns. The bi-directional reflectance has units of sr^{-1}. In the calling sequence the variables are:

CTHIN - cosine of incident zenith angle

CTHOUT - cosine of exit zenith angle

CPHOUT - cosine of the azimuthal angle between the incident and exit planes

ALAM - wavelength, μm

KCLOUD - not used.

A linear interpolation is performed between wavelengths but no angular interpolation is utilized.

3-2.7 Subroutine CLDGEOM

Required bookkeeping for cloud "facets" is accomplished in this routine. See Figure 3-2 for a flow chart. A maximum of 20 deterministic clouds can be considered in a given job. Areas of the facets, radii to their centers, coordinates of the boundaries, and coordinates of the centers are evaluated and stored in common CDCORD for use by other routines. There is no requirement for user interaction with this subroutine, unless he wants to consider the irradiance on a particular facet and facet orientation to the source and detector. To do so would require a code modification.

Coordinates of the facets are computed according to the prescription:

$$\theta_1 = 0$$

$$\theta_2 = \frac{\pi}{2} \frac{1}{1 + (R1)^{\alpha} + (R1)^{2\alpha} + (R1)^{3\alpha}}$$

$$\theta_3 = [1 + (R1)^{\alpha}]\, \theta_2$$

$$\theta_4 = \frac{\pi}{2} - (R1)^{3\alpha}\, \theta_2$$

$$\theta_5 = \frac{\pi}{2}$$

$$\Delta = \frac{\pi}{2} \frac{1}{1 + (R2)^{\beta} + (R2)^{2\beta} + (R2)^{3\beta}}$$

$$\phi_1 = 0$$

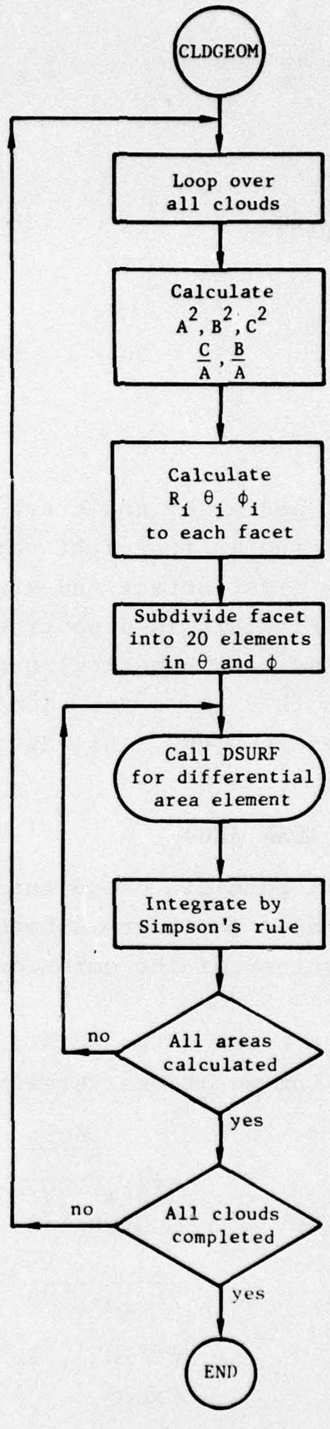


Figure 3-2. Flow chart of subroutine CLDGEOM.

$$\phi_2 = (R2)^{3\beta}\ \Delta$$

$$\phi_3 = \frac{\pi}{2} - [1 + (R2)^{\beta}]\ \Delta$$

$$\phi_4 = \frac{\pi}{2} - \Delta$$

$$\phi_5 = \frac{\pi}{2}$$

where R1 is c/a, R2 is b/a, and a, b, and c are the semi-axis lengths. These coordinates are reflected in the eight octants; consequently, they are calculated only for the first octant and are mapped to the other seven by the function IPRIME. This is also true of areas and radii.

Areas are evaluated by a numerical quadrature (Simpson's rule) using twenty intervals in both θ and ϕ for each facet. Differential area elements are calculated in DSURF. All data obtained from, and returned to, common arrays.

3-2.8 Subroutine CLDWT(ALAM,ANG)

Weightings for all possible cloud and cloud-layer combinations are evaluated in this routine. These are subsequently assigned to the transfer coefficients and values of the emission as calculated by calls to TRANSF and EMISSF.

The correspondence between the notation used in Section 2-2 and that used in the following equations is given below:

Section 2-2	Here
W(clear)	$WT_{new}(160)$
P(cc=1)	CCOVER(1)
$\sum_{i=1}^{159} [1-W(i)]$	$WT_{old}(160)$
W(i), i=1,159	WT(IDX), IDX=1,159
$CFLOS_{cc}(\theta)$	$CFLOS_c$

For any of the 10 location-season averaged cloud models (KMODEL = 1,10), WT(IDX) is the probability that (a) the cloud-configuration set indicated by the index IDX occurs and (b) the LOS at zenith angle θ_e intersects the cloud-configuration set. The total probability of the LOS intersecting clouds is

$$\sum_{IDX=1}^{159} WT(IDX) \quad .$$

The probability that the LOS does not intersect the clouds but "sees through" the clouds is

$$WT_{old}\ (160) \quad .$$

The probability of seeing the ground without any clouds being present is

$$CCOVER\ (1) \quad .$$

(For brevity we have suppressed the index KMODEL on which the array CCOVER depends.) The probability of seeing the ground either with or without clouds being present is

$$WT_{new}\ (160) = WT_{old}\ (160) + CCOVER\ (1) \quad .$$

The probability of seeing either clouds or the ground (with or without clouds being present) is

$$\sum_{IDX=1}^{159} WT(IDX) + WT_{new}\ (160) = 1 \quad .$$

$$WT(I) = \sum_{C=1}^{4} CCOVER(C+1)\ (1-CFLOS_c)$$

$$\cdot \begin{cases} \cdot\ CF(15,C) \cdot \begin{cases} TL \cdot \dfrac{CF(L,C)}{TL} & L=1,7 \quad I=1,7 \\[2ex] TM \cdot \dfrac{CF(7+M,C)}{TM} & M=1,3 \quad I=8,10 \\[2ex] TH \cdot \dfrac{CF(10+H,C)}{TH} & H=1,4 \quad I=11,14 \end{cases} \\[8ex] \cdot\ CF(16,C) \cdot \begin{cases} \dfrac{TL \cdot TM}{DEN} \cdot \dfrac{CF(L,C) \cdot CF(7+M,C)}{TL \quad \cdot \quad TM} & \begin{array}{l} L=1,7 \\ M=1,3 \end{array} \quad I=15,35 \\[3ex] \dfrac{TL \cdot TH}{DEN} \quad \dfrac{CF(L,C) \cdot CF(10+H,C)}{TL \quad \cdot \quad TH} & \begin{array}{l} L=1,7 \\ H=1,4 \end{array} \quad I=36,63 \\[3ex] \dfrac{TM \cdot TH}{DEN} \quad \dfrac{CF(7+M,C) \cdot CF(10+H,C)}{TM \quad \cdot \quad TH} & \begin{array}{l} M=1,3 \\ H=1,4 \end{array} \quad I=64,75 \end{cases} \\[8ex] \cdot\ CF(17,C) \ \cdot\ 1 \cdot \dfrac{CF(L,C) \cdot CF(7+M,C) \cdot CF(10+H,C)}{TL \quad \cdot \quad TM \quad \cdot \quad TH} & \begin{array}{l} L=1,7 \\ M=1,3 \\ H=1,4 \end{array} \quad I=76,159 \end{cases}$$

where

$CF \equiv CFREQ$

$TL \equiv TOTL$

$TM \equiv TOTM$

$TH \equiv TOTH$

$DEN \equiv TL \cdot TM + TL \cdot TH + TM \cdot TH$

The probability of seeing the ground through the clouds is

$$WT_{old}(160) = \sum_{C=1}^{4} CCOVER(C+1) \bullet CFLOS_c \bullet \sum_{\ell=1}^{3} CF(14+\ell,C)$$

$$\bullet \left\{ \begin{array}{ll} \displaystyle\sum_{j=1}^{3} U(j|\ell=1,C) \bullet \sum_{K=KMIN_j}^{KMAX_j} \frac{CF(K|j,C)}{T_j} & \\ \qquad \text{DO-loops } 101,\ 102,\ 103 & \ell=1 \\ \displaystyle\sum_{j=1}^{2} \sum_{j'>j}^{3} V(j,j'|\ell=2,C) \sum_{K=KMIN_j}^{KMAX_j} \sum_{K'=KMIN_{j'}}^{KMAX_{j'}} \frac{CF(K|j,C) \bullet CF(K'|j',C)}{T_j \bullet T_{j'}} & \\ \qquad \text{DO-loops } 200,\ 201,\ 202 & \ell=2 \\ \displaystyle W(1,2,3|\ell=3,C) \sum_{K=1}^{7} \sum_{K'=8}^{10} \sum_{K''=11}^{14} \frac{CF(K|1,C) \bullet CF(K'|2,C) \bullet CF(K''|3,C)}{T_1 \bullet T_2 \bullet T_3} & \\ \qquad \text{DO-loops } 300 & \ell=3 \end{array} \right.$$

$$= \sum_{C=1}^{4} CCOVER(C+1) \bullet CFLOS_c = \sum_{C=1}^{4} \frac{CFLOS_c}{1-CFLOS_c} \sum_{I=1}^{159} WT(I,C)$$

Here, $U(j|\ell=1,C)$ is the probability of layer j, given one layer and cloud-coverage index C

$V(j,j'|\ell=2,C)$ is the probability of layers j and j', given two layers and index C

$W(1,2,3|\ell=3,C)$ is the probability of layers 1,2,3, given three layers and index C

These probabilities satisfy the following relations:

$$\sum_{j=1}^{3} U(j|\ell=1,C) = \sum_{j=1}^{3} T_j = \sum_{j=1}^{3} \sum_{K=KMIN_j}^{KMAX_j} CF(K|j,C) = 1$$

$$\sum_{j=1}^{2} \sum_{j'>j}^{3} V(j,j'|\ell=2,C) = \frac{\sum\sum T_j \; T_{j'}}{\sum\sum T_j \; T_{j'}} = 1; \quad W(1,2,3|\ell=3,C) = 1$$

$$\text{The probability of seeing clouds} = \sum_{I=1}^{159} WT(I)$$

$$= \sum_{C=1}^{4} CCOVER\ (C+1) \bullet (1-CFLOS_c) \sum_{\ell=1}^{3} CF(14+\ell,C)$$

$$\bullet \left\{ \begin{array}{ll} \displaystyle\sum_{j=1}^{3} U(j|\ell=1,C) \sum_{K=KMIN_j}^{KMAX_j} \frac{CF(K|j,C)}{T_j} & \ell=1 \\ \displaystyle\sum_{j=1}^{2} \sum_{j'>j}^{3} V(j,j'|\ell=2,C) \sum_{K=KMIN_j}^{KMAX_j} \sum_{K'=KMIN_{j'}}^{KMAX_{j'}} \frac{CF(K|j,C)}{T_j} \frac{CF(K'|j',C)}{T_{j'}} & \ell=2 \\ \displaystyle W(1,2,3|\ell=3,C) \sum_{K=1}^{7} \sum_{K'=8}^{10} \sum_{K''=11}^{14} \frac{CF(K|1,C)}{T_1} \bullet \frac{CF(K'|2,C)}{T_2} \bullet \frac{CF(K''|3,C)}{T_3} & \ell=3 \end{array} \right.$$

$$= \sum_{C=1}^{4} CCOVER(C+1) \cdot (1-CFLOS_c) \quad .$$

The probability of seeing either clouds or the ground (with or without clouds)

$$= \sum_{I=1}^{159} WT(I) + WT_{old}(160) + CCOVER(1)$$

$$= \sum_{C=1}^{4} CCOVER(C+1) \left[1 - CFLOS_c + CFLOX_c\right] + CCOVER(1)=1 \quad .$$

3-2.9 Subroutine CLOUDO(MODE)

For a detailed description of CLOUDO see Section 4-2.

3-2.10 Subroutine CLOUD1

Coordinates of the source (XI,ETA,ZETA) and detector (XID, ETAD,ZETAD) are calculated in the Cartesian coordinate system of each cloud with the quantities stored in common CDCORD. Entry CLD E TO C in subroutine CLOUD9 is used to transform from earth to cloud coordinates.

3-2.11 Subroutine CLOUD2(UL,VL,WL)

The altitude (ALTLK(K)) and geographic coordinates (THETALK(K), PHILK(K)) of the intersection of the line-of-sight and the Kth deterministic cloud are calculated in this routine and outputted in common INTRCPT. These results are not used by other cloud-model routines. However, this routine is a convenience to the user. The sight-path integration module can use results of this routine to avoid calling the cloud transfer-coefficient routine (CLOUD3) until the sight-path integration has reached the cloud top.

The input to this subroutine are the direction cosines (UL,VL,WL) of the line-of-sight. The point of intersection is calculated for all clouds which fall in the path. A flow chart is shown in Figure 3-3.

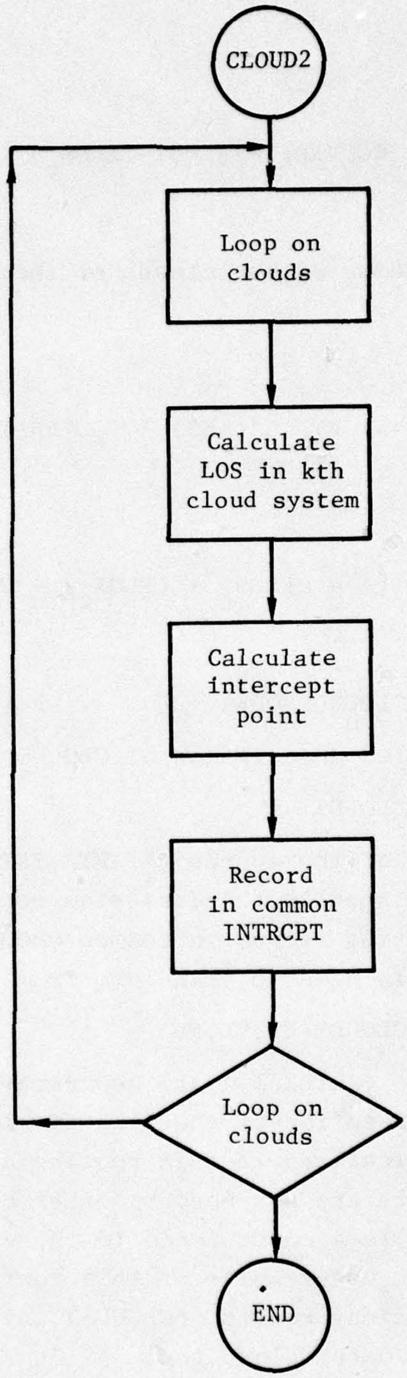


Figure 3-3. Flow chart of subroutine CLOUD2.

3-2.12 Subroutine CLOUD3(UL,VL,WL,K,ALAM,TCOEF,EMISS,SINCLD)

When all of the bookkeeping has been accomplished, CLOUD3 is called to calculate the transfer coefficient (TCOEF) and the emission (EMISS). Branching is required depending upon whether or not the point of intersection of the LOS with the cloud is visible to the source. For those LOS-intersection points which are also illuminated, the bidirectional reflectance is obtained from tables in function CLDBDR. The tabulated values are functions of incident and exit zenith angles and the exit azimuthal angle. The bidirectional reflectance is picked from a bin with no interpolation. The tables are, however, interpolated linearly as a function of wavelength.

The irradiance to all illuminated facets is evaluated. A diffusion calculation is then performed in subroutine DIFFUS to get the radiance exiting the facet of interest.

The thermal emission is calculated from the Planck distribution for the temperature at the point of intersection of the cloud top and line-of-sight.

Before the source irradiation of a cloud is computed, a check is made to determine whether or not the source is either inside the cloud or on its surface. If the source is not outside the cloud, a warning message is printed and, without further calculation, the routine returns a logical variable (SINCLD = .TRUE.) to the main program (ROSCOER) which then proceeds to the next case.

We have also devised a prescription which is used if the artificial (point) source is closer to the cloud surface than (approximately) the radius R_s that is assigned to the finite-size artificial source. Let $\vec{RP}$ be the position of the source in the cloud coordinate system and $\vec{RS}$ be the radial distance to the intersection point S of the ray RP with the cloud surface. At point S the outward unit normal is $\hat{n}(\vec{RS})$. Then, for the purpose of this routine, if

$$(\vec{RP}-\vec{RS}) \cdot \hat{n}(\vec{RS}) < R_s \quad ,$$

the source is moved in the direction of $\hat{n}(\vec{RS})$ an amount δP given by

$$\delta P = 0.5\,[R_s - (\vec{RP}-\vec{RS}) \cdot \hat{n}(\vec{RS})] \quad .$$

A message is printed with the original and altered coordinates of the source.

3-2.13 Subroutine CLOUD9(RTP1,RTP2,RTP3,EC1,EC2,EC3,K)

Transformations are made between the earth-centered polar coordinate system and the cloud-centered Cartesian system of the Kth cloud. This routine has two entry points. Entries CLD E TO C and CLD C TO E transform from earth to cloud and cloud to earth, respectively.

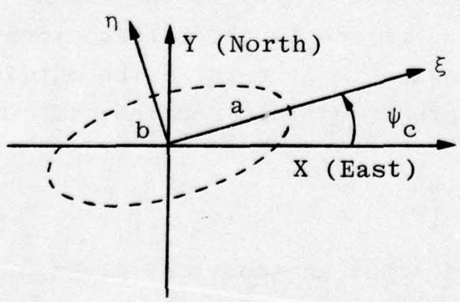
The cloud geometry is most easily described in the cloud principal-axis system (ξ, η, ζ) in which the equation of the cloud surface is

$$\frac{\xi^2}{a^2} + \frac{\eta^2}{b^2} + \frac{\zeta^2}{c^2} = 1 \quad .$$

The location of the cloud center (earth-centered polar coordinates) is (R_c, θ_c, ϕ_c) where

$$R_c = R_{earth} + H_c, \; H_c = \text{HCLOUD (km)}$$
$$\theta_c = \text{THETCD (degrees)}$$
$$\phi_c = \text{PHICD (degrees)}.$$

Looking from above the cloud toward the earth center:



$$\left.\begin{aligned} \psi_c &= \text{CLDPSI} \\ \xi &= X \cos \psi_c + Y \sin \psi_c \\ \eta &= Y \cos \psi_c - X \sin \psi_c \\ \zeta &= Z \; . \end{aligned}\right\} \quad (1)$$

The transformation from the earth-centered Cartesian system (x,y,z) to the non-rotated (ψ_c=0) Cartesian system (X,Y,Z) in the cloud can be performed with two rotations and one translation.

The first intermediate coordinate system (x',y',z') is obtained by making a counterclockwise (positive) rotation

$$\phi = \phi_c + \pi/2$$

about the z-axis such that the x'-axis is normal to the vector $\vec{R}_c$ to the cloud center. The (π/2)-term is introduced to make the positive X-axis of the cloud point east. The transformation is

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = R_1(\phi) \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

where the transformation matrix R_1 is given by

$$R_1(\phi) = \begin{pmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{pmatrix} .$$

The second intermediate coordinate system (z",y",z") is obtained by making a counterclockwise (positive) rotation θ_c about the x'-axis such that the z'-axis lies along the vector $\vec{R}_c$. The transformation is

$$\begin{pmatrix} x'' \\ y'' \\ z'' \end{pmatrix} = R_2(\theta) \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

where

$$R_2(\theta) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{pmatrix} .$$

Finally, the non-rotated cloud system (X,Y,Z) is related to the (x",y",z") system by a translation along the z"-axis:

$$Z = z'' - R_c$$

where

$$R_c = R_{earth} + H_c \quad .$$

Collating our results we have

$$\begin{pmatrix} X \\ Y \\ Z+R_c \end{pmatrix} = \begin{pmatrix} x'' \\ y'' \\ z'' \end{pmatrix} = R_2(\theta)R_1(\phi) \begin{pmatrix} x \\ y \\ z \end{pmatrix} \tag{2a}$$

with

$$R_2(\theta)R_1(\phi) = \begin{pmatrix} -\sin\phi_c & \cos\phi_c & 0 \\ -\cos\theta_c \cos\theta_c & -\cos\theta_c \sin\phi_c & \sin\theta_c \\ \sin\theta_c \cos\phi_c & \sin\theta_c \sin\phi_c & \cos\theta_c \end{pmatrix} . \tag{2b}$$

Thus, an arbitrary point in earth-centered polar coordinates (R, Θ, Φ) has earth-centered Cartesian coordinates (x,y,z) and cloud principal-axis coordinates (ξ,η,ζ) where

$$(x,y,z) = (R \sin\Theta \cos\Phi,\ R \sin\Theta \sin\Phi,\ R \cos\Theta)$$

and the coordinates (X,Y,Z) and (x,y,z) are related by Equations (2a) and (2b). Finally (ξ,η,ζ) and (X,Y,Z) are related by Equation (1), or equivalently

$$\begin{pmatrix} \xi \\ \eta \\ \zeta \end{pmatrix} = R_1(\psi_c) \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} .$$

The transformation from the cloud system to the earth system may be done by doing the same steps in reverse order and using the transposed transformation matrices.

3-2.14 Subroutine CONVERT(R,TH,PH,X,Y,Z)

This subroutine has entry points to transform from polar to Cartesian and Cartesian to polar coordinates. The entry points are POL TO CT and CT TO POL with arguments as follows:

Y - Cartesian X-coordinate
Y - Cartesian Y-coordinate
Z - Cartesian Z-coordinate
R - Radius in spherical coordinate system
TH - Polar angle in spherical coordinate system
PH - Azimuthal angle in spherical coordinate system.

3-2.15 Subroutine DIFFUS(K,ALAM)

The computations involved in subroutine DIFFUS are those from Appendix A and as described in Section 2-1. Communication with this routine is from CLOUD3.

3-2.16 Subroutine DIFPRM(ALAM)

Given a wavelength between two and five microns, this subroutine interpolates microscopic scattering and extinction cross-sections in μm^2, coverts to macroscopic cross-sections in units of km^{-1}, and records the modified diffusion parameters, as defined in Section A-1.2, for each of the 14 cloud types of the data base.

<u>INPUT</u>:

ALAM: wavelength of photon (μm)

<u>OUTPUT</u>: (common DIFFUS, arrays of 14-word length)

DALFA ≡ a in Appendix A Equation (2) (dimensionless)
DBETA ≡ b in Appendix A Equation (2) (km)
DKAPPA ≡ K in Appendix A Equation (19) (km^{-1})

For large-particle-size clouds (i.e., cloud-types 11,12,13 and 14), the small wavelength approximations $\sigma_T = 2\pi\overline{r}^2$ and $\sigma_S = (1+W)\pi\overline{r}^2$ are used. Here, 1 and W are, respectively, the diffracted and specular-reflected components of the scattering.

3-2.17 Function DSURF(THETA,PHI,K)

Differential area elements on the surface of an ellipsoid are calculated in this routine as a function of θ and ϕ. The cloud number K must also be transmitted to the function as it obtains the ellipsoidal parameters from common CDCORD.

3-2.18 Function EMISSF(ALAM,LL,MM,HH)

This function provides the thermal emission (W/(km^2 sr μm)) from clouds, attenuated by clear air to an altitude of 12 km.

3-2.19 Subroutine ESURF(THI,THR,PSI,ZKM,MSM,DD,SPCULR,ZLAM,IDAY, IFIRES,ESURFI,SFR,EPSD,TKS)

This subroutine, a dummy routine for the real one, provides the surface upwelling radiation and earth bidirectional reflectance. The description is given in Reference 6.

3-2.20 Function IPRIME(II)

This function provides a mapping of the facet areas and radii onto those of the first octant. This symmetry is utilized to obviate storing redundant data.

3-2.21 Subroutine LINEAR(XD,FXD,XX,FXX,NX)

LINEAR performs a linear interpolation with an expeditious technique to find the pair of tabular points which bound the point of interest. The interpolation is then

$$Y = Y_{i-1} + \frac{Y_i - Y_{i-1}}{X_i - X_{i-1}} (X - X_{i-1}) \quad .$$

INPUTS:

- XX: array of points in independent variable
- FXX: array of points in dependent variable
- NX: number of points in the table
- X0: value of independent variable for which dependent variable is desired.

OUTPUTS:

- FX0: dependent variable at value of X0 in independent variable.

3-2.22 Subroutine LOS(K)

Possible lines-of-sight from which the user can select directions are computed and stored in common LOS. There are selection rules based on several criteria. A line-of-sight must obviously intercept a cloud facet; however, the facet is not necessarily illuminated. Facets which would fall within the same field-of-view are not duplicated. See Figure 3-4 for a flow chart.

The first criterion selects first the facets which are both visible and illuminated and orders these from smallest to largest scattering angle. Those facets which are visible but not illuminated are then ordered according to their being closest to the edge of the cloud. The rationale for this ordering is that the cloud will be thinnest along the line-of-sight near the edge.

This routine can produce a maximum of 16 possible lines-of-sight. For a small cloud and large field-of-view, there could possibly be only one.

3-2.23 Function PS(X1,ET1,ZET1,THETA,PHI,K)

This function evaluates a quantity which is proportional to the dot product of the normal to the ellipsoid and a vector from the surface point to the external point. If the quantity is negative, the point is shadowed from the line-of-sight; if positive, the point is visible.

3-2.24 Function RHOEPS(ALAM,CTHETA)

This function evaluates the hemispherical-directional reflectance from the (horizontal) surface of cloud-type 4 (stratocumulus) for radiation of wavelength ALAM reflected into zenith angle $\cos^{-1}$ (CTHETA).

Tabulated in an array called RHO is a set of hemispherical-directional reflectances for the stratocumulus cloud model at wavelengths between 2 and 5 microns and for exit zenith angles whose cosines are 1.0, 0.866, 0.5, and 0.0. The value of 0.0 is a fictitious endpoint to the table to accommodate interpolation. Interpolation is linear in wavelength and cosine theta.

<u>INPUT</u>:

ALAM: wavelength of photon (μm)

CTHETA: cosine of zenith angle for which emissivity is desired.

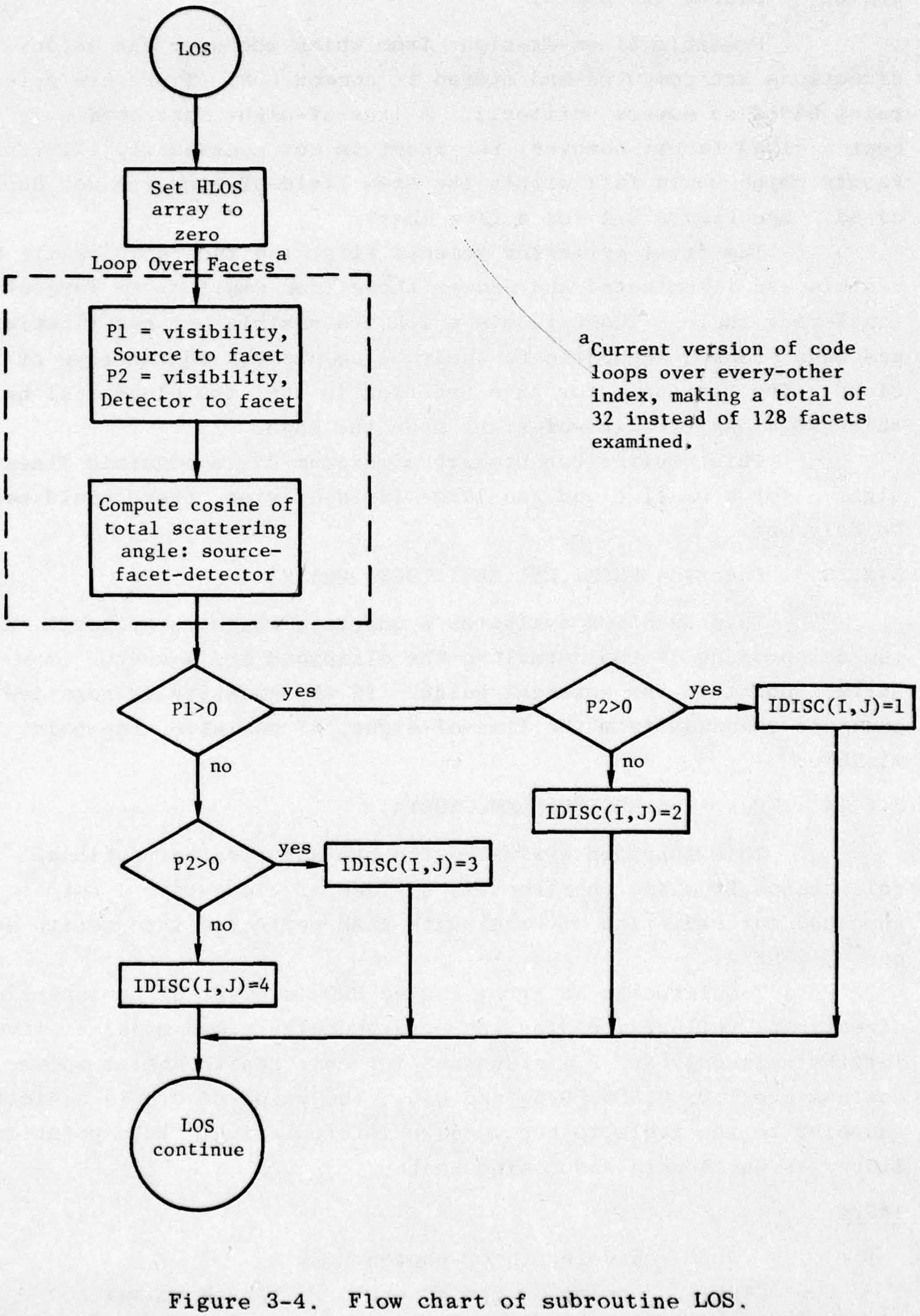


Figure 3-4. Flow chart of subroutine LOS.

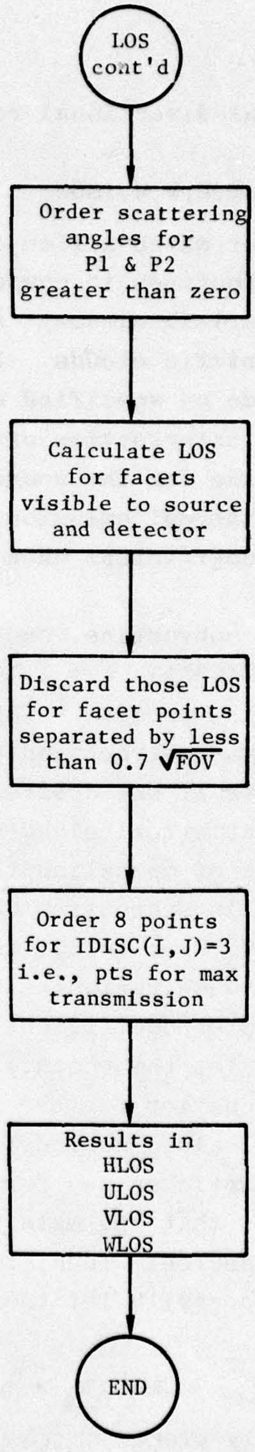


Figure 3-4. Flow chart of subroutine LOS (Cont.).

OUTPUT:

RHOEPS: hemispherical-directional reflectance .

3-2.25 Subroutine SCLOUD(ALAM,U,V,W,ISUN)

Subroutine SCLOUD, for which a flow chart is given in Figure 3-5, calls in the required subroutines to compute transfer coefficients and thermal emission for statistical clouds. A source position must be specified, just as for deterministic clouds. It is also required that the solar longitude and latitude be specified when the solar position is above the local horizon at the intersection of the line-of-sight with the earth. Calculations are made for the source (burst) and solar transfer coefficients and the thermal emission. Calculations are bypassed for the solar transfer coefficient when the sun is below the local horizon.

By interrupting this subroutine, one has access to the entire cumulative arrays (TRANS(I), EMISS(I), I = 1,160) in addition to the four fractiles returned to the calling program. This could easily become a normal mode of operation for system-type studies. Also, this (non-implemented) mode is appropriate if one desires calculations for a specific realization of the statistical cloud configurations without going to the deterministic mode of operating the code.

Subroutine SCLOUD calls subroutine CLDWT to obtain TRANS(I), EMISS(I), and WT(I) for I=1,159. For I=160, when the LOS is cloud-free and terminates on the ground, these variables are evaluated in subroutine SCLOUD. In computing the transfer coefficient for I=160, one could get arbitrarily large values if he let the (point) source get arbitrarily close to the ground (cf. the equation for the reflectance transfer coefficient for the statistical cloud submodel near the end of Section 2). To prevent getting such unrealistic values for the transfer coefficient, we have imposed the requirement that the main program assign a radius R_s to the finite-size artificial source. Then, if the altitude h_s of the source is less than R_s, we temporarily let the effective altitude of the finite-size source be

$$h_{eff} = 0.5\ (R_s + h_s) \quad .$$

Thus, if the source is initially placed on the ground so that $h_s = 0$, our prescription places the effective altitude at 0.5 R_s.

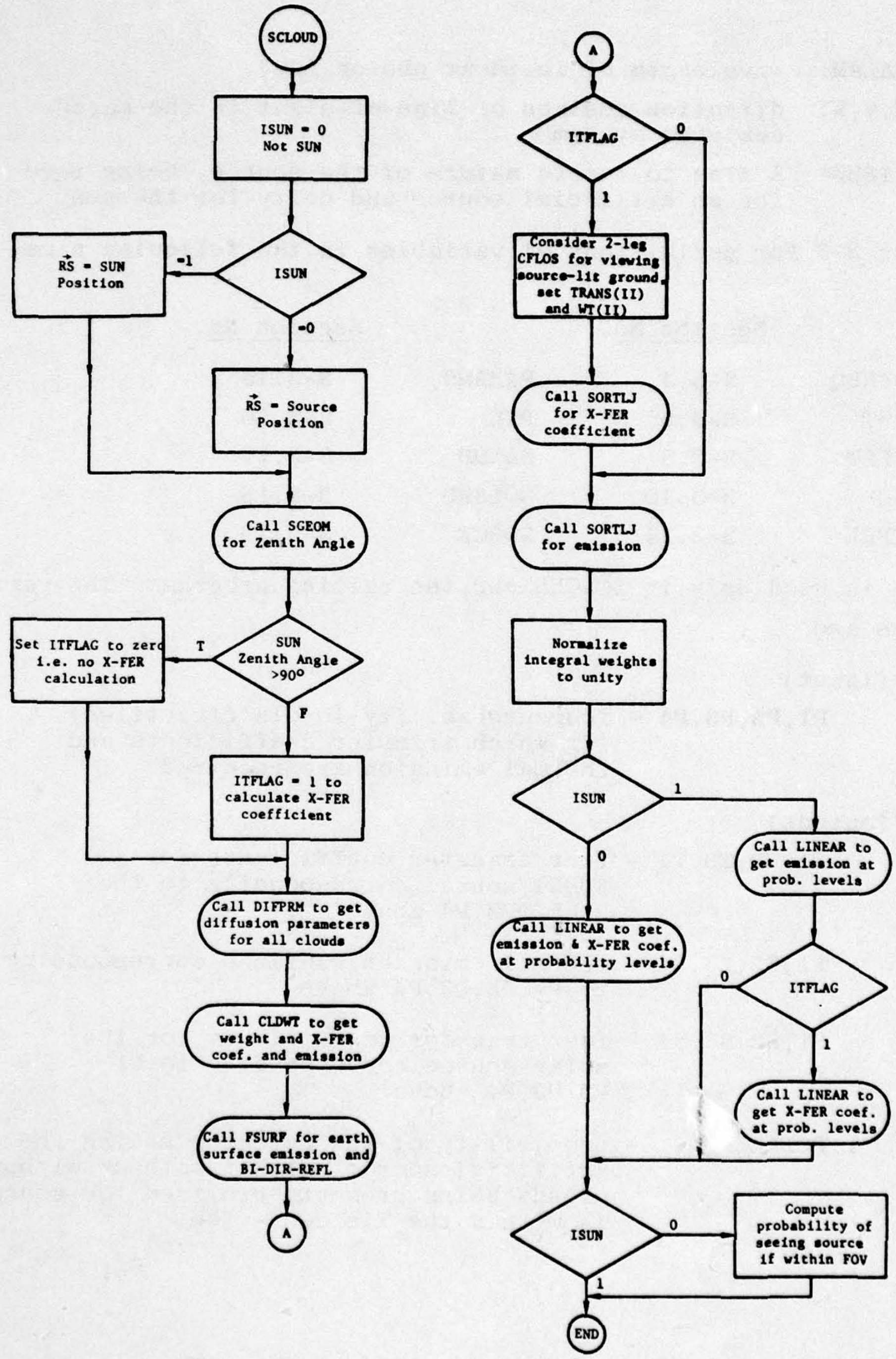


Figure 3-5. Flow chart of subroutine SCLOUD.

INPUTS:

ALAM: wavelength of incident photon (μm)

U,V,W: direction cosines of line-of-sight in the earth-centered system

ISUN: A flag to denote nature of the source, being zero for an artificial source and unity for the sun.

See Section 3-3 for definitions of variables in the following name commons:

	Section No.		Section No.
CLDFREQ	3-3.4	PARAMS	3-3.15
CLDWT	3-3.5	PTE	3-3.16
DETECT	3-3.8	SANDD	3-3.17
FLAGS	3-3.10	SOLARP	3-3.18
MATERL	3-3.14	SORCE	3-3.19

Common PTE is used only in SCLOUD and the calling program. The variable definitions are

(input)

P1,P2,P3,P4 - four probability levels (fractiles) for which transfer coefficients and thermal emission are required.

(output)

T1,T2,T3,T4 - four transfer coefficients for a NUDET source corresponding to the P1,P2,P3,P4 above

E1,E2,E3,E4 - thermal emission radiance corresponding to P1,P2,P3,P4 above

S1,S2,S3,S4 - four transfer coefficients for the solar source corresponding to P1, P2,P3,P4 above

PCFLOS - probability of the detector seeing the artificial source, either with or without clouds being present, provided the source is within the field-of-view.

3-2.26 Subroutine SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,RDIST, SDIST,THETI,THETE,PHIE)

Subroutine SGEOM, for which a flow chart is given in Figure 3-6, computes the incident and exit zenith angles and the azimuthal scattering angle for a specified source and detector geometry and a given line-of-sight. Also evaluated is the distance (SDIST) from the source to the cloud-LOS intersection point and the horizontal component thereof (RDIST).

INPUTS:

- UL,VL,WL: direction cosines of the line-of-sight in the earth-centered coordinate system
- CLDTOP: altitude of top of cloud or other specified altitude (km)
- XD,YD,ZD: rectangular components of detector position vector in earth-centered system (km)
- XS,YS,ZS: rectangular components of source position vector in earth-centered system (km)

OUTPUTS:

- SDIST: distance from source to intersection of line-of-sight with cloud top (km)
- RDIST: horizontal component of SDIST (km)
- THETI: zenith angle to source position at intersection point of LOS with CLDTOP-altitude (degrees)
- THETE: zenith angle to detector position (degrees)
- PHIE: azimuthal angle of scattering of photon (degrees)

3-2.27 Subroutine SORTLJ(A,B,C,N,LOHI)

This subroutine sorts an array in either ascending or descending order and carries two additional arrays with the ordering. The argument-list variables are as follows:

A is the array to be sorted

B array carried along with the sorting on A

C array carried along with the sorting on A

N is the number of elements in arrays A,B, and C

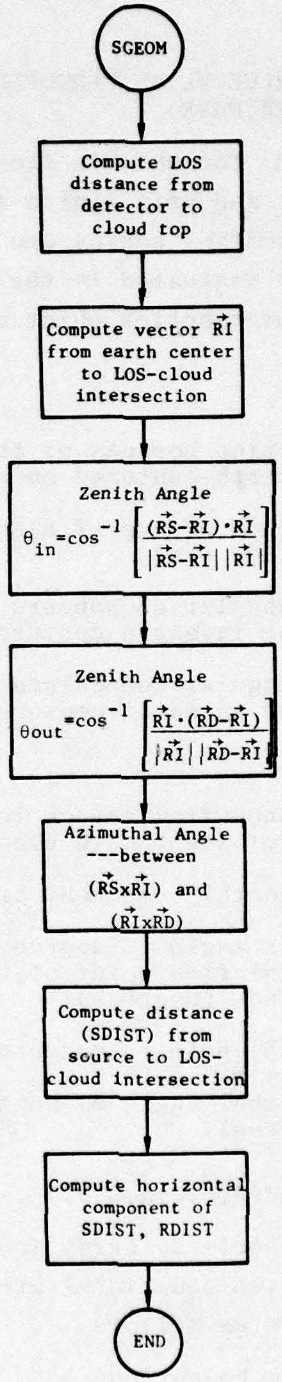


Figure 3-6. Flow chart of subroutine SGEOM.

LOHI is the ordering flag

> >0 sorts from high to low
>
> ≤ 0 sorts from low to high.

3-2.28 Function TAIR(ALAM,THETA,ALT)

Air transmittance, T, for radiation of wavelength λ from altitude h to 12 km along a path at zenith angle θ was calculated using LOWTRAN 3 for the U.S. 1962 Standard Atmosphere. The data are cataloged in this function.

The independent variables are:

wavelength: $2 \leq \lambda \leq 5$ microns

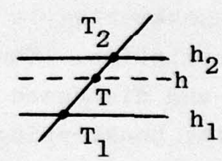
zenith angle: $0 \leq \theta \leq 85$ degrees

altitude: $1 < h < 12$ kilometers.

The interpolation (and extrapolation for $\theta > 85$ degrees and $h < 1$ km) used is linear in (T,λ)-, $(\ln T, \sec\theta)$-, and $(\ln T,h)$-space. More explicit formulas follow:

<u>Altitude</u>

$$T = ae^{bh}$$



$$b = \ln\left(\frac{T2}{T1}\right) \Big/ (h_2 - h_1)$$

$$a = T_1 e^{-bh_1} \;,$$

which implies

$$\ln T = \ln T_1 - (\ln T_1 - \ln T_2)\,\frac{h-h_1}{h_2-h_1} \;.$$

<u>Angle</u>

$$T = ab^{\sec\theta}$$

$$b = (T_2/T_1)^{(\sec\theta_2 - \sec\theta_1)^{-1}}$$

$$a = T_1/b^{\sec\theta_1} \;,$$

which implies

$$\ln T = \ln T_1 + (\ln T_2 - \ln T_1)\left[\frac{\sec\theta - \sec\theta_1}{\sec\theta_2 - \sec\theta_1}\right] .$$

For θ >85 degrees, we redefine $\sec\theta$ by a parabolic approximation to the Chapman function,

$$\sec\theta = \sec\ (85\ \text{deg}) + 1.1\ (\theta - 85)^2 \quad .$$

<u>Wavelength</u>

$$T = T_1 + (T_2 - T_1)\ \frac{\lambda - \lambda_1}{\lambda_2 - \lambda_1} \quad .$$

3-2.29 Function TRANSF(ALAM,LL,MM,HH)

This function evaluates the transfer coefficient for the set of statistical clouds whose indexes are in the calling sequence: Considerable bookkeeping is accomplished to assign the calculation to the proper prescription. The prescriptions are adequately documented in Appendix A and discussed in Section 2-2.

The bookkeeping, in general, evaluates the diffusion parameters for the appropriate layer number and stores them according to the required variable name for the prescription. The first steps are to determine how many layers are involved in the problem, whether the source is inside or outside, and whether the cloud layers are continuous. These questions are answered and control transferred to the equation for

reflection,
1-layer transmission for source inside,
1-layer transmission for source below,
2-layer transmission for source below,
or 3-layer transmission for source below.

The results are then normalized to get a transfer coefficient, TRANSF, which is returned to subroutine CLDWT.

If the altitude ALT of an artificial source above the top of the topmost layer is less than the radius R_s assigned to the finite-size source, the effective altitude of the source in computing the reflectance transfer coefficient is reset to

$$h_{eff} = \text{CLDTOP} + 0.5\ (\text{ALT} + R_s) \quad .$$

3-2.30 Subroutine VSNORM(X,Y,Z,EN1,EN2,EN3,K)

This subroutine computes a unit vector $\hat{n}$ normal to the surface of the ellipsoid at the Cartesian coordinates x,y,z in cloud K.

$$\hat{n} = \frac{1}{Q}\left[\frac{x}{a^2}\,\hat{i} + \frac{y}{b^2}\,\hat{j} + \frac{z}{c^2}\,\hat{k}\right]$$

$$Q = \left[\left(\frac{x}{a^2}\right)^2 + \left(\frac{y}{b^2}\right)^2 + \left(\frac{z}{c^2}\right)^2\right]^{\frac{1}{2}} \quad .$$

3-3 LABELED COMMON VARIABLE DEFINITIONS

Variables in labeled common are described in this section. Since the subroutines which use these variables are designed to be utilized as part of other codes, i.e., the subroutines are submodules, names are located in labeled commons which will tend to minimize their conflict with other code variable names. A list of the names of labeled commons and the subroutines in which they are found is located in Table 3-1.

The name of each common and the variables which are contained therein will be listed just as they are found in the subroutines. A brief description and the variable units follow the statement.

3-3.1 COMMON/ATMOUP/DUM1(4),RHO,TT,DUM2(22)

RHO: RHO(g/cm^3), the air density at altitude z(km), is used by the main program ROSCOER to scale the radius of the artificial source with altitude.

TT: TT (degrees Kelvin), the air temperature at altitude z(km), is used by the cloud routines.

(RHO and TT, the only two variables from this common, are obtained by a call to ATMOSU(2,ZH), where ZH is the altitude of interest, (km)).

Table 3-1. List of subroutines and labeled commons.

SUBROUTINE \ COMMON	ATMOUP	CDCORD	CDDATA	CLDFREQ	CLDWT	CLOUD	CONFIG	DETECT	DIFFUS	FLAGS	FLUX	INTRCPT	LOS	MATERL	PARAMS	PTE	SANDD	SOLARP	SORCE	XX1111
ROSCOER	X					X		X				X	X	X	X	X	X	X	X	X
ATMOSU	X																			
BLKDAT			X	X																
CLDBDR			X																	
CLDGEOM		X				X									X					
CLDWT				X	X		X													
CLOUD0				X		X	X								X					
CLOUD1		X				X		X							X				X	
CLOUD2		X				X		X				X			X					
CLOUD3	X	X				X		X			X				X				X	X
CLOUD9						X									X					
DIFFUS		X	X			X					X				X					
DIFPRM			X						X						X					
DSURF		X																		
EMISSF	X		X												X		X			
LOS		X				X		X					X		X					
PS		X													X					
SCLOUD				X	X			X		X				X	X	X	X	X	X	
SGEOM															X					
TRANSF			X						X	X					X		X		X	
VSNORM		X																		

3-3.2 COMMON/CDCORD/XI(1,20),ETA(1,20),ZETA(1,20),XID(20),ETAD(20), ZETAD(20),ASQ(20),BSQ(20),CSQ(20),CPH(5,20),CTH(5,20),CPHBAR (16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)

Variables in this common provide communication between the geometry routines of the deterministic cloud calculations. Calculations relative to a given cloud are made in a coordinate system centered on that cloud and results, if required, are transformed back to the earth-centered system. Ellipsoidal elemental areas used in integration are referred to as facets.

XI,ETA,ZETA: Cartesian coordinates of the Nth source in the Kth cloud-centered system. N currently is restricted to one. (km)

XID,ETAD,ZETAD: Cartesian coordinates of the detector in the Kth cloud-centered system. (km)

ASQ,BSQ,CSQ: Values of the squares of the semi-axes of an ellipsoid. (km^2)

CPH: Cloud-centered azimuthal angle bounding a facet or area on the surface of the cloud. (radians)

CTH: Cloud-centered polar angle bounding a facet on the surface of the cloud. (radians)

CPHIBAR: Cloud-centered azimuthal angle locating a facet center in the Kth cloud. Symmetry is taken into account in the eight octants. (degrees)

CTHBAR: Cloud-centered polar angle locating a facet center in the Kth cloud. (degrees)

CRBAR: Distance from the cloud center to the facet center, utilized in calculating fluxes. All symmetry is taken into account and the function IPRIME locates the element in the CRBAR array which has the proper distance to one of the 128 facets when there are 16 azimuthal angles and 8 polar angles. (km)

CAREA: Areas of the facets are calculated by a 2-dimensional Simpson's rule of integration in subroutine CLDGEOM with the differential area element being calculated in DSURF. Again, function IPRIME returns the proper index to obtain the desired area element. (km^2)

3-3.3 COMMON/CDDATA/ALAMT(10),SIGT(10,14),SIGS(10,14),W(10), XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)

Data in this common are physical and optical properties of the cloud data base. Physical properties are taken from the NASA cloud data base and optical properties for cloud types 1 through 10 are from Mie theory calculations. There are 14 types of clouds in this data base for which data are tabulated at ten wavelengths.

ALAMT: ALAMT is a table of wavelengths for which microscopic cross-sections and mean cosines of scattering angles are tabulated. Values are 2.0, 2.5, 2.55, 2.65, 2.75, 2.85, 3.2, 3.5, 4.0, and 5.0. (μm)

SIGT: Microscopic extinction cross-sections for the 14 cloud types are tabulated at the 10 wavelengths of the ALAMT table. (μm^2)

SIGS: Scattering cross-sections for the 14 cloud types are tabulated at the 10 wavelengths of the ALAMT table. (μm^2)

W: (Normalized) contribution of specularly-reflected radiation to scattered radiation, with the diffracted radiation contributing unity; used only for the large-particle-size clouds, types 11 through 14. (dimensionless)

XMUBAR: Cosine of the scattering angle averaged over the particle size distribution of the cloud type and tabulated at the 10 wavelengths. (dimensionless)

DNO: Droplet density of the given cloud type. (droplets/cm^3)

RAD: Mean droplet radius for the cloud type. (μm)

CLDBASE: Cloud-base altitudes for the 14 cloud types. (km)

CLDTHK: Cloud thickness. (km)

3-3.4 COMMON/CLDFREQ/KMODEL,CCOVER(5,11),CLDFREQ(17,4,11)

Common CLDFREQ has its origin in block data. The index KMODEL selects one of the ten sets of data present in data statements or allows a user-supplied set of data to be input as the eleventh set of data.

KMODEL: A variable which selects the cloud data base to be used in the calculations.

=1 for dry annual average

=2 for dry winter average night

=3 for dry winter average day

=4 for dry summer average night

=5 for dry summer average day

=6 for moist annual average

=7 for moist winter average night

=8 for moist winter average day

=9 for moist summer average night

=10 for moist summer average day

=11 for array supplied by the user.

See Section 4 for a detailed illustration of using KMODEL = 11.

CCOVER: This array provides the probability of the Lth cloud-coverage category for the Kth model, K being defined above, where

$$\sum_{L=1}^{5} \text{CCOVER}(L,K) = 1 \quad .$$

For the K = 11 base, the input instructions in Section 4 illustrate the use of the table. CCOVER(L,K) is a frequency of occurrence of the Lth coverage category.

CLDFREQ: With the indexes (I,L,K), CLDFREQ(I,L,K) is the frequency of the Ith cloud type for I less than fifteen. For I = 15,16,17 it is the frequency of occurrence of 1-layer, 2-layers, or 3-layers, respectively. For K-values between 1 and 10 (inclusive) the array elements are from the model as defined under KMODEL above. For K = 11, the use of the table is described in Section 4. Basically, however, each element is the frequency of the Ith type of cloud:

I=1 for Cu1	I=8 for Ac
I=2 for Cu2	I=9 for As1
I=3 for Cu3	I=10 for Cb2
I=4 for Sc	I=11 for Cb3
I=5 for St	I=12 for As2
I=6 for Cb1	I=13 for Ci
I=7 for Ns	I=14 for Cs

3-3.5 COMMON/CLDWT/IDX,WT(160),TRANS(160),EMISS(160)

The common array WT contains the probability of a given statistical cloud configuration, i.e., the product of the probability of a given cloud-coverage category, the probability of the number of layers in that coverage category, and the probability of an occurrence of a cloud type in that layer and category configuration. This configuration is ultimately weighted by one minus the cloud-free line-of-sight for this cloud coverage and zenith angle.

There are 160 combinations of layer-type-coverage configurations. Subsets of restrictions on any of the components, e.g., coverage category, reduces the 160 to a fewer number of cases.

IDX: This is the total number of configurations which is always less than 160. With a maximum constraint, it can be as few as two, i.e. the cloud type (with coverage category specified) and the cloud-free line-of-sight component.

WT: WT(IDX) is the probability of the IDXth configuration. IDX is less than or equal to 160.

TRANS: TRANS(IDX) is the transfer coefficient for the IDXth configuration. It corresponds to either a transmission or a reflection and includes attenuation by the atmosphere (1962 U.S. standard via LOWTRAN-3) to an altitude of 12 km. (sr^{-1})

EMISS: EMISS(IDX) is the thermal emission spectral radiance attenuated to 12-km altitude. ($W/(km^2\ sr\ \mu m)$)

3-3.6 COMMON/CLOUD/NCLOUD,HCLOUD(20),THETCD(20),PHICD(20), CLOUDA(20),CLOUDB(20),CLOUDC(20),CLDPSI(20),KCLOUD(20)

Input deterministic cloud descriptions are read into these arrays by subroutine CLOUDO. As many as twenty clouds can be part of the calculations; however, there are no interacting clouds, i.e., reflections of one cloud to another are not considered.

NCLOUD: Number of deterministic clouds for which altitude, orientation, and semiaxes are to be read into the arrays. This variable is used as the upper limit on DO-loops throughout the code.

THETCD: Colatitude of the cloud. (degrees)

PHICD: East longitude of the cloud. (degrees)

CLOUDA: Semiaxis of the longer cloud axis in horizontal plane. (km)

CLOUDB: Semiaxis of the shorter cloud axis in the horizontal plane. (km)

CLOUDC: Semiaxis of the cloud in vertical direction. (km)

The values of a,b, and c are those in the equation of an ellipsoid:

$$\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{c}\right)^2 = 1$$

CLDPSI: Azimuthal angle, measured counterclockwise looking down, orienting cloud about (vertical) z-axis. Clouds are normally oriented with (+a)-axis eastward (psi = 0). (degrees)

KCLOUD: Index for Kth cloud, representing one of the 14 cloud types from the data bank.

3-3.7 COMMON/CONFIG/CTYPL(8),CTYPM(4),CTYPH(5),CFLAG,C1,C2

This common is a bit unwieldy but is used in the input routine CLOUD0. The entries are the Hollerith names of the cloud types in the low, middle, or high layer.

CTYPL(LL): Type of cloud LL ($1 \leq LL \leq 7$) or no cloud (LL=8) in the low layer. The variable is left-justified in 5-column fields.

CTYPM(MM): Type of cloud MM ($1 \leq MM \leq 3$) or no cloud (MM=4) in the middle layer.

CTYPH(HH): Type of cloud HH ($1 \leq HH \leq 4$) or no cloud (HH=5) in the high layer.

CFLAG: CFLAG is a coverage category flag. (Not utilized)

C1: C1 is the (integer) index for the first cloud-coverage category being utilized. Normally C1 is 2.

C2: C2 is the upper limit counterpart of C1. Normally C2 is 5.

3-3.8 COMMON/DETECT/HD,THETAD,PHID,FOV

This common contains the location of the detector in an earth-centered polar coordinate system.

HD: Altitude of the detector. (km)

THETAD: Colatitude of detector. (degrees)

PHID: East longitude of detector. (degrees)

FOV: Field-of-view (FOV) of the detector (km^2). Radiances in the deterministic cloud calculations are averaged over the field-of-view. The FOV is also used in subroutine LOS, as potential lines-of-sight are separated by the order of the square root of the FOV.

3-3.9 COMMON/DIFFUS/DALFA(14),DBETA(14),DKAPPA(14)

This common contains the coefficients in the diffusion equation for photon flux transmitted through clouds. They are generated for all fourteen clouds by a single call to DIFPRM for a specified wavelength.

DALFA: Diffusion parameter defined in Appendix A-1.2. (unitless)

DBETA: Diffusion parameter defined in Appendix A-1.2. (km)

DKAPPA: Diffusion parameter defined in Appendix A-1.2. (km^{-1})

3-3.10 COMMON/FLAGS/ITFLAG

This common is currently used only to avoid calculation of the transfer coefficient in function TRANSF in the statistical calculations when only the thermal emission is needed.

ITFLAG: ITFLAG turns off the transfer coefficient computation as described above.

3-3.11 COMMON/FLUX/FIN(8,16),FOUT(8,16)

This common provides communication between subroutine CLOUD3, which generates the input FIN to subroutine DIFFUS and uses the output FOUT, and the subroutine DIFFUS. DIFFUS effects the diffusion solution to get the photon flux output at each of the facets, given the input flux.

FIN: This is 4π times the photons km^{-2} sec^{-1} that are incident normally on each of the cloud facets which are visible to the unit strength, isotropic source.

FOUT: This is 4π times the photon flux (radiant emittance) that is transmitted by each facet, according to the diffusion theory approximation. (4π photons/(km^2 sec), for unit-strength source).

3-3.12 COMMON/INTRCPT/ALTLK(20),THETALK(20),PHILK(20)

This common provides communication between subroutine CLOUD2 and the calling program which is requesting the geographic location of the intersection of the line-of-sight and the cloud.

ALTLK: The altitude at which the line-of-sight intercepts the Kth cloud. (km)

THETALK: The colatitude of the Kth cloud intercept. (degrees)

PHILK: The east longitude of the Kth cloud intercept. (degrees)

3-3.13 COMMON/LOS/HLOS(1,64),ULOS(1,64),VLOS(1,64),WLOS(1,64)

This common contains lines-of-sight to all facets of deterministic clouds which provide reflectance and to those facets which have the highest transmission. These are provided following a call to subroutine LOS with the argument K for the Kth cloud.

HLOS: Altitude at which the line-of-sight from the detector intercepts the Jth facet in the Kth cloud. (km, above mean sea level)

ULOS,VLOS,WLOS: Direction cosines in the earth-centered Cartesian system, of the above-described lines-of-sight.

Each of the vectors (ULOS,VLOS,WLOS) provides to the code user a potential line-of-sight which is separated by approximately the square root of the field-of-view from another possible line-of-sight.

3-3.14 COMMON/MATERL/MSM,DDM(7),SRFALT

MSM: Integer defining susface type.

=1 for Lambertian diffuse surface with spectrally-independent reflectance set by DD(1) and emissivity by (1.-DD(1)).

=2 for water

=3 for snow

=4 for sand

=5 for soil

=6 for foilage

=7 for urban material

DDM(M): Additional descriptor for selected surface material. See comments in subroutine ESURF, a routine provided by the model documented in Reference 6.

SRFALT: Surface altitude. (km)

3-3.15 COMMON/PARAMS/IN,IOUT,PI,RE,DTR,RTD

This common contains program constants, set in program ROSCOER, which are frequently used in numerous routines. The constants can be replaced by equivalencing or renaming variables.

IN: The integer variable name used to identify the input file unit. It is not used consistently.

IOUT: The integer variable name which identifies the output file unit. It is not used consistently.

PI: The value of PI as used throughout the program. It has the numerical value of 3.14159265.

RE: The value used for the Earth's radius and has a numerical value of 6371.03 km.

DTR: This is the conversion factor to convert from degrees to radians and has a numerical value of 0.01745329251994.

RTD: This is the conversion factor from radians to degrees and has a numerical value of 57.2957795131.

3-3.16 COMMON/PTE/P1,P2,P3,P4,T1,T2,T3,T4,S1,S2,S3,S4,E1,E2,E3,E4

P1...P4: Probability fractiles at which transfer coefficients and emission radiances are desired. Set in program ROSCOER.

T1...T4: Transfer coefficients at 12-km altitude for point source. This is the ratio of a radiance to an irradiance. (sr^{-1})

S1...S4: Transfer coefficients at 12-km altitude for sun as a source. (sr^{-1})

E1...E2: Thermal emission (spectral radiance) from top layer of clouds or the ground (for the cloud-free line-of-sight). ($W/(km^2\ sr\ \mu m)$)

PCFLOS: Probability of the detector seeing the artificial source, either with or without clouds being present, provided the source is within the field-of-view.

3-3.17 COMMON/SANDD/XS,YS,ZS,XD,YD,ZD,UL,VL,WL

The common SANDD contains the Cartesian coordinates of the location of both the source and detector, and the direction cosines of the line-of-sight.

XS,YS,ZS: Cartesian coordinates of the source location in the earth-centered system. The x-direction points to zero degrees longitude and ninety degrees colatitude. The z-direction is through the north pole. (km)

XD,YD,ZD: Cartesian coordinates of the detector location in the earth-centered system. (km)

UL,VL,WL: Direction cosines of the line-of-sight vector in the earth-centered system.

3-3.18 COMMON/SOLARP/SOLLAT,SOLLON

SOLLAT: Solar latitude in earth-centered polar coordinates with positive being north of the equator. (radians)

SOLLON: Solar (east) longitude in earth-centered polar coordinates. (radians)

3-3.19 COMMON/SORCE/NSORCE,HSORCE(1),THETAS(1),PHIS(1),RSORCE(1)

NSORCE: This variable is not utilized in this version of the code, and it is always set to one.

HSORCE: Altitude of source. (km)

THETAS: Colatitude of source. (degrees)

PHIS: East longitude of source. (degrees)

RSORCE: Radius of source. (km)

3-3.20 COMMON/XX1111/KCLDK,CLDLAM

KCLDK: A test-flag used in subroutine CLOUD3 to determine whether CLOUD3 is now being called with the same cloud-number K as for its last call.

CLDLAM: A test quantity used in subroutine CLOUD3 to determine whether CLOUD3 is now being called with the same wavelength ALAM as for its last call.

Note: If K and ALAM inputted to subroutine CLOUD3 have the same values as in the last call, the subroutine bypasses its call to subroutine DIFFUS(K,ALAM). Both KCLDK and CLDLAM are initialized in the main program to the arbitrary, out-of-range values of 99 and -99., respectively.

SECTION 4
DATA REQUIREMENTS AND SAMPLE PROBLEMS

4-1 DATA REQUIRED FOR STATISTICAL AND DETERMINISTIC CLOUDS

Required user-supplied data for transmission of IR signatures through clouds are read by CLOUDO. Many of the data, as outlined in the following paragraphs, are stored in the program and the code need only be directed by an appropriate flag to use them. Consequently, only a few directives need be inputted to run standard cases. Data cataloged in the program are described first, followed by descriptions and illustrations for user-supplied data.

Data which are cataloged are accessible to both the statistical and deterministic submodules. Only a limited number of sets of data are included in the code to demonstrate the utility of the code without its becoming unwieldy.

Cloud descriptions in terms of mean water droplet radius (μm), droplet density (cm^{-3}), base altitude (km), and thickness (km) are incorporated into the code via BLOCK DATA. These data are tabulated in Table 2-1. Microscopic extinction and scattering cross-sections (μm^2) and average cosine of the scattering angle, averaged (as described in Reference 2) over droplet size distributions from Table 2-1, are also included in BLOCK DATA for 14 cloud types and 10 wavelengths in the 2- to 5-μm range. No provision has been made to replace or adjust these parameters for user-supplied data. A modification could be implemented to provide such an option.

The only bidirectional reflectance data that are in the code are those for a stratocumulus cloud, a frequently occurring cloud type according to the NASA cloud-data bank. The tables in function CLDBDR are rather lengthy. Some considerable effort has been expended to fit the bidirectional reflectance data for inclusion in the code; however, the code contains only tabulated data.

The cloud-frequency data are stored in an array (CFREQ) in BLOCK DATA dimensioned (14 + 3) by 4 by (10 + 1). For each of the 10 (or 11 including the user-option case) region-averaged data sets, there

are 14 cloud-frequency numbers and three layer-frequency numbers for each of the four nonclear coverage categories. Each specification requires five coverage categories, of which four are independent, ranging from completely clear to complete cloud-cover.

Nominal statistical-cloud data sets are included in the program which include averages over summer, winter, day, night, and annual for a dry and a moist region. They are arranged as in Table 4-1.

4-2. USER-REQUIRED AND USER-OPTIONAL DATA FOR NATURAL CLOUD MODULES

For utilizing the ROSCOE-IR natural cloud module in a stand-alone mode, several data are required to be read by the driver program ROSCOER. ROSCOE-IR will provide these data to the natural cloud module as implemented in the ROSCOE-IR code. The requirements for the driver program will be described first, followed by the description of inputs read by subroutine CLOUDO. Sufficient information is included to illustrate the options and to provide test cases for the stand-alone mode.

Detector and source locations are read by the driver program ROSCOER. The first input record contains H, θ, ϕ, and FOV for the detector; the second record contains the same information (less the FOV) for the source. H is the altitude in kilometers, ϕ is the colatitude (degrees), and is the east longitude (degrees). FOV is the field-of-view (km^2) for the detector. The third input record contains the flag ISUN which is zero if the only source to be considered is the artificial source and which is unity if the sun is to be considered as a source in addition to the artificial source. The solar location is specified in a data statement in ROSCOER. The fourth input record is the wavelength ALAM.

Subroutine CLOUDO, for which a flow diagram is shown in Figure 4-1, reads all of the user-supplied data and sets the proper flags for subsequent code execution. For the statistical case, only data are read; the deterministic mode (MODE=0) also causes the geometry routines (CLDGEOM, and, in turn, DSURF) to be called.

The flags are set by Card 1 and Card 2.

Card 1: MODE (I10 format)
= 0 Deterministic model
= 1 Statistical model
(branch here to required submodule)

Table 4-1. Cloud data bank contained in ROSCOE natural cloud program.

Index for Statistical Cloud Set	Region	Type of Average
1	Dry[a]	Annual
2	Dry[a]	Winter night
3	Dry[a]	Winter day
4	Dry[a]	Summer night
5	Dry[a]	Summer day
6	Moist[b]	Annual
7	Moist[b]	Winter night
8	Moist[b]	Winter day
9	Moist[b]	Summer night
10	Moist[b]	Summer day
11	Array reserved for user-supplied data	

[a,b]Regions 4 and 11 in Reference 1 nomenclature, i.e., continental and maritime.

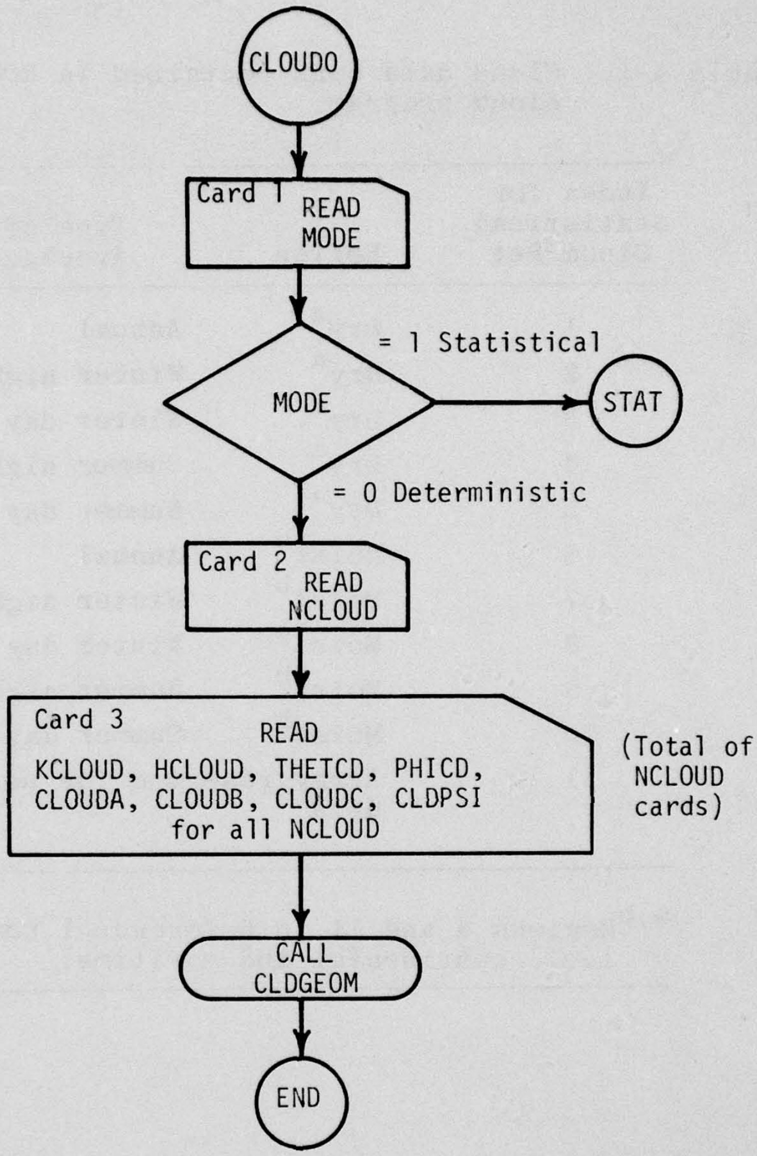


Figure 4-1. Flow chart of subroutine CLOUDO. (Continued on next page.).

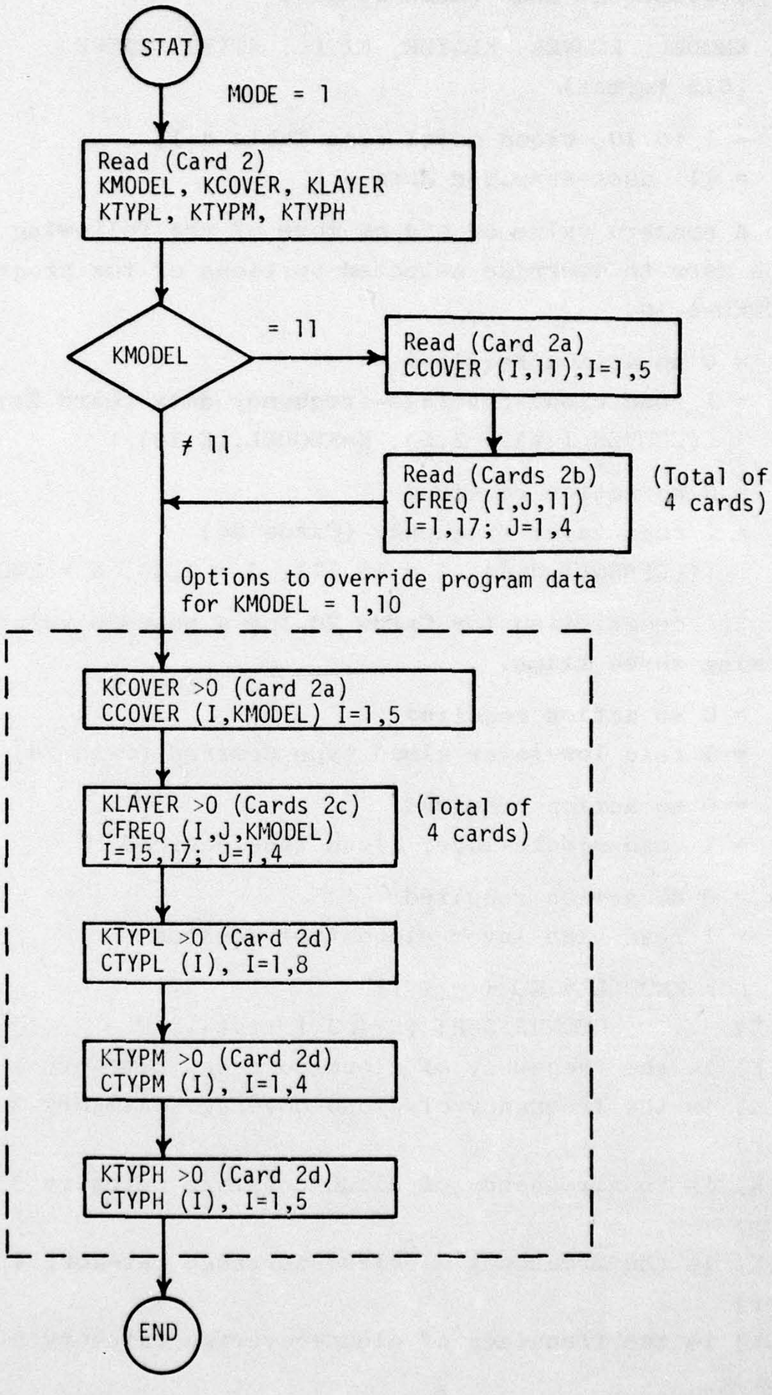


Figure 4-1. Flow chart of subroutine CLOUDO (Cont.).

4-2.1 Statistical Mode (MODE=1) Data

Card 2: KMODEL, KCOVER, KLAYER, KTYPL, KTYPM, KTYPH (6I5 format)

KMODEL = 1 to 10, cloud model (see Table 4-1)
= 11, user-supplied data

A nonzero value of one or more of the following five flags allows the user to override selected portions of the program data for a given KMODEL=1,10.

KCOVER = 0 no action required
= 1 read cloud-coverage-frequency data (Card 2a)
((CCOVER(I,K),I=1,5), K=KMODEL.LE.10)

KLAYER = 0 no action required
= 1 read layer frequency (Cards 2c)
(((CFREQ(I,J,K), I = 15,17), J = 1,4), K = KMODEL.LE.10)

See description for Cards 2d for a nonzero value of any of the following three flags.

KTYPL = 0 no action required
= 1 read low-layer cloud type desired (Card 2d)

KTYPM = 0 no action required
= 1 read middle-layer cloud type desired

KTYPH = 0 no action required
= 1 read high-layer cloud type desired

Card 2a: for KMODEL = K, K = 1,11

CCOVER(1,K), ... , CCOVER(5,K) (5F4.3 format)

CCOVER(1,K) is the frequency of cloud-coverage category 1 (clear)

CCOVER(2,K) is the frequency of cloud-coverage category 2 (0.3 cloud cover)

CCOVER(3,K) is the frequency of cloud-coverage category 3 (0.5 cloud cover)

CCOVER(4,K) is the frequency of cloud-coverage category 4 (0.8 cloud cover)

CCOVER(5,k) is the frequency of cloud-coverage category 5 (complete cover)

$$\text{where } \sum_{I=1}^{5} \text{CCOVER}(I,K) = 1.0 \quad .$$

Cards 2b: for KMODEL = 11 (four cards)

CFREQ(I,J,11)	$1 \leq I \leq 17$, $1 \leq J \leq 4$		(17F4.3 format)
CFREQ(1,J,K)	is frequency of	CU1	low-altitude clouds
CFREQ(2,J,K)	is frequency of	CU2	
CFREQ(3,J,K)	is frequency of	CU3	
CFREQ(4,J,K)	is frequency of	SC	
CFREQ(5,J,K)	is frequency of	ST	
CFREQ(6,J,K)	is frequency of	CB1	
CFREQ(7,J,K)	is frequency of	NS	
CFREQ(8,J,K)	is frequency of	AC	mid-altitude clouds
CFREQ(9,J,K)	is frequency of	AS1	
CFREQ(10,J,K)	is frequency of	CB2	
CFREQ(11,J,K)	is frequency of	CB3	high-altitude clouds
CFREQ(12,J,K)	is frequency of	AS2	
CFREQ(13,J,K)	is frequency of	CI	
CFREQ(14,J,K)	is frequency of	CS	

where

$$\sum_{I=1}^{14} \text{CFREQ}(I,J,K) = 1.$$

CFREQ(15,J,K)	is frequency of	1 layer
CFREQ(16,J,K)	is frequency of	2 layers
CFREQ(17,J,K)	is frequebcy of	3 layers

where

$$\sum_{I=15}^{17} \text{CFREQ}(I,J,K) = 1.$$

Cards 2c: for K = KMODEL = 1,10 (3F4.3 format) (four cards)

Cards 2c provide a mechanism to change layer frequencies for KMODEL <11, i.e., (((CFREQ(I,J,KMODEL), I=15,17),J=1,4), KMODEL<11) without changing the individual cloud-type frequencies.

CFREQ(I,J,K), I=15,16,17 and J=1,2,3,4

I=15 is the frequency of 1 layer
=16 is the frequency of 2 layers
=17 is the frequency of 3 layers

Cards 2d: cloud-type specification (8A5 format)
(one, two, or three cards)
Read under 8A5 format (a blank field rejects that cloud type). Data must be left-justified.

For KTYPL = 1 (one card):

```
CTYPL(I), I=1,8
CTYPL(1) = CU1
CTYPL(2) = CU2
CTYPL(3) = CU3
CTYPL(4) = SC
CTYPL(5) = ST
CTYPL(6) = CB1
CTYPL(7) = NS
CTYPL(8) = CLR = clear
```

For KTYPM = 1 (one card):

```
CTYPM(I), I = 1,4
CTYPM(1) = AC
CTYPM(2) = AS1
CTYPM(3) = CB2
CTYPM(4) = CLR
```

For KTYPH = 1 (one card):

```
CTYPH(I), I = 1,5
CTYPH(1) = CB3
CTYPH(2) = AS2
CTYPH(3) = CI
CTYPH(4) = CS
CTYPH(5) = CLR
```

By utilizing combinations of Card 1 through Cards 2d, one can accomplish any degree of specification desired. However, for a complete specification, the problem reduces to that of a deterministic calculation where the thicknesses and altitudes come from the program data bank and the cloud is infinite in lateral extent.

4-2.2 Deterministic Mode (MODE=0) Data

Card 2: NCLOUD (I10 format)

Card 3: KCLOUD(I), HCLOUD(I), THETCD(I), PHICD(I)
CLOUDA(I), CLOUDB(I), CLOUDC(I), CLDPSI(I)
where $1 \leq I \leq$ NCLOUD
(I2, E8.3, 6E10.4 format)

KCLOUD(I) = Cloud-type index of Ith cloud (1,2,...,14)
HCLOUD(I) = Altitude of Ith cloud (km)
THETCD(I) = Colatitude of Ith cloud (degrees)
PHICD(I) = East longitude of Ith cloud (degress)
CLOUDA(I) = Semi-axis in x-direction of Ith cloud (km)
CLOUDB(I) = Semi-axis in y-direction of Ith cloud (km)
CLOUDC(I) = Semi-axis in z-direction of Ith cloud (km)
CLDPSI(I) = Orientation of the a-axis with respect to the east-west direction, i.e., ψ orients the longest (a-axis) at an angle of ψ degrees north of east.

4-3. SAMPLE PROBLEMS

A number of sample computer runs have been made using the ROSCOE natural cloud program. Several of these are included here to facilitate subsequent code comparisons. Listings of input cards necessary for each problem are provided.

Some modifications of the code were required to obtain the data output shown in the samples. Code calculations were affected only as outlined below. Print statements were placed in the code to intercept calculations in a convenient manner for presentation. These are given in Appendix C to facilitate reproducing the output for each problem.

4-3.1 Problems 1 to 4: Use of the Statistical Cloud Submodel in a Limited, Deterministic Mode (with KMODE1=1,10)

The purpose of these four problems, which form a set, is (1) to illustrate use of the statistical cloud submodel in a limited, deterministic mode (with KMODEL=1,10) and (2) to show that diffusion calculations performed by the code for a point source beneath either (a) single-layer (planar) clouds or (b) multilayer (planar) clouds are in good agreement with exact, analytic diffusion calculations.

To help provide the motivation for a portion of these problems, we note that the total transmittance T for a planar slab is given by Equation (31a) of Appendix A, i.e.,

$$T = Q \left[\cosh KL + \tfrac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right)\sinh KL\right]^{-1}$$

where Q, the total flux into the slab, can be set to unity. To get a computer code result that can be compared with this transmittance, we must take several steps:

a. Instruct the code to treat a single planar cloud above a point source.

b. Compute the radial distribution of the transmission transfer coefficients, without including air attenuation.

c. Convert this distribution of transfer coefficients to a radial distribution of radiant exitance.

d. Integrate this radial distribution of radiant exitance across the cloud top and divide by the spatially-integrated flux into the slab to obtain a total transmittance.

The quantity that the code was actually instructed to compute is one we shall refer to as a modified transfer coefficient, TC', in units of km^{-2} sr^{-1}. These units are those of the transfer coefficient (sr^{-1}) divided by the square of the distance from the source to the 12-km altitude transfer point. These units are equivalent to describing TC' as being 4π times the radiance (W km^{-2} sr^{-1}) directed toward the downward-looking radial-scanning detector, for a unit strength isotopic source. (Alternatively, TC' is 4 times the radiant exitance.) This modified transfer coefficient, $4\pi L$, was divided by 4π and multiplied by π to obtain the radiant exitance and was subsequently integrated across the cloud-top radial distribution. Division by the source power incident on the underside of the cloud gave the total transmittance T:

$$T = \frac{1}{(\frac{1}{2}\text{ source power})} \int_0^\infty \left(\frac{4\pi L}{4\pi}\,\pi\right) 2\pi r dr \quad .$$

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THE ROSCOE MANUAL. VOLUME 24. NATURAL CLOUDS (PHYSICAL AND OPTI--ETC(U)
JUL 79 R R JOHNSTON, D E STEVENSON, W A ARON DNA001-76-C-0194
UNCLASSIFIED SAI-78-604-LJ-5-VOL-24 DNA-3964F-24 NL

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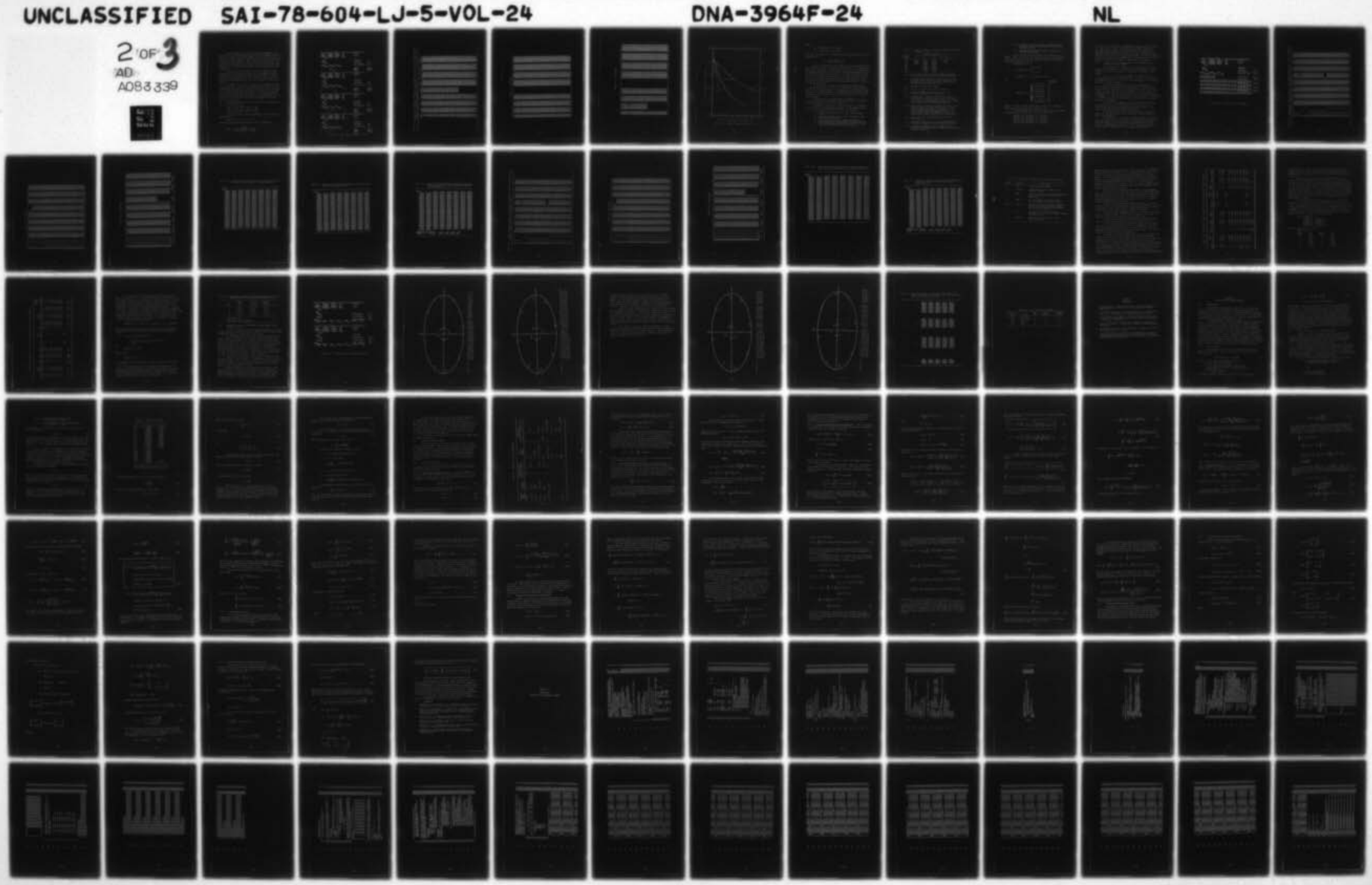

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2 OF 3

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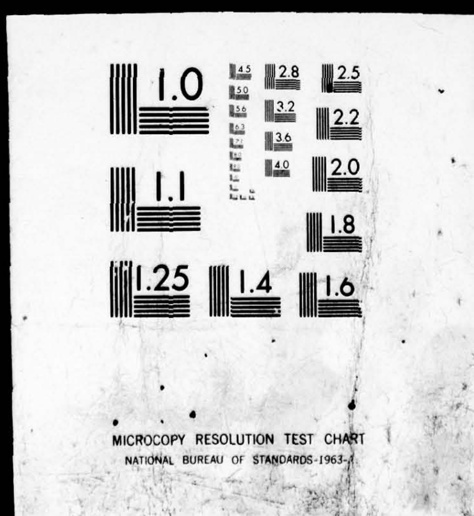

The information on the input cards read by ROSCOER for the detector, source, and wavelength and by subroutine CLOUDO for Cards 1,2 and 2d (cf. Figure 4-1 and corresponding text) is given in Figure 4-2 for the four sample problems. Each of the first three problems treats a different single cloud type, namely, Type 4 (Sc), Type 8 (Ac), and Type 13 (Ci), respectively; the fourth problem treats the three-layer configuration of these same cloud types. We shall discuss the input cards later.

For each of the four problems, and for a range of lateral displacements in 0.25-km steps, the values of the modified transfer coefficient, $4\pi L$, are given in Columns 2 to 5 of Table 4-2. These quantities are plotted in Figure 4-3. Columns 6 to 9 of Table 4-2 give the corresponding values of the radial integrals for the transmittance.

In Figure 4-3 the curve for cloud Sc is not shown at larger distances because it soon develops wiggles and, starting at 35.75 km, an occasional negative value. These features result from limitations of the internal integration scheme which is intended to be efficient in the lateral range of importance but not at very large distances. The curve for cloud Ac begins to wiggle a bit at about 20 km, that for cloud Ci at about 30 km, and that for the combined set of clouds (Sc + Ac + Ci) at 7 km.

The analytic results for the transmittance and reflectance of each of the three layers are:

$$T(Sc) = 0.820 \times 10^{-2} \quad R(Sc) = 0.653$$
$$T(Ac) = 0.113 \times 10^{-1} \quad R(Ac) = 0.637$$
$$T(Ci) = 0.127 \times 10^{-6} \quad R(Ci) = 0.0761$$

The analytic result for the transmittance of the three-layer configuration is

$$T(Sc + Ac + Ci) = 0.211 \times 10^{-10}$$

which was evaluated from the formula, derived in Appendix D,

$$T_{123} = \frac{T_1 T_2 T_3}{(1-R_1R_2)(1-R_2R_3) - R_1R_3T_2^{\,2}}$$

```
****************** PROBLEM 1  ***********************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1)  THETAS(1)   PHIS(1)     WKT                 SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
        1
   ALAM                                                WAVELENGTH
  2.50
     MODE                                              STATISTICAL        CARD 1
        1
 KMODEL     KLAYER      KTYPM                          USER CLOUD MODEL   CARD 2
      KCOVER      KTYPL       KTYPH
  1    0     0     1     1     1
                  SC                                   LAYER 1            CARD 2D
                  CLR                                  LAYER 2            CARD 2D
                           CLR                         LAYER 3            CARD 2D
****************** PROBLEM 2  ***********************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1)  THETAS(1)   PHIS(1)     WKT                 SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
        1
   ALAM                                                WAVELENGTH
  2.50
     MODE                                              STATISTICAL        CARD 1
        1
 KMODEL     KLAYER      KTYPM                          USER CLOUD MODEL   CARD 2
      KCOVER      KTYPL       KTYPH
  1    0     0     1     1     1
                                        CLR            LAYER 1            CARD 2D
AC                                                     LAYER 2            CARD 2D
                           CLR                         LAYER 3            CARD 2D
****************** PROBLEM 3  ***********************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1)  THETAS(1)   PHIS(1)     WKT                 SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
        1
   ALAM                                                WAVELENGTH
  2.50
     MODE                                              STATISTICAL        CARD 1
        1
 KMODEL     KLAYER      KTYPM                          USER CLOUD MODEL   CARD 2
      KCOVER      KTYPL       KTYPH
  1    0     0     1     1     1
                                        CLR            LAYER 1            CARD 2D
                  CLR                                  LAYER 2            CARD 2D
          CI                                           LAYER 3            CARD 2D
****************** PROBLEM 4  ***********************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1)  THETAS(1)   PHIS(1)     WKT                 SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
        1
   ALAM                                                WAVELENGTH
  2.50
     MODE                                              STATISTICAL        CARD 1
        1
 KMODEL     KLAYER      KTYPM                          USER CLOUD MODEL   CARD 2
      KCOVER      KTYPL       KTYPH
  1    0     0     1     1     1
                  SC                                   LAYER 1            CARD 2D
AC                                                     LAYER 2            CARD 2D
          CI                                           LAYER 3            CARD 2D
```

Figure 4-2. Input data for Problems 1 to 4.

Table 4-2. Data output for sample problems 1 to 4. Columns 2 to 4 give the cloud-top radiance L times 4π as a function of lateral displacement (km) from a unit-strength source at 0.01-km altitude. Wavelength is 2.5 μm.

RANGE	SC	AC	CI	SC-AC-CI	INT(SC)	INT(AC)	INT(CI)	INT(TOTAL)
.00	.2247E-02	.3315E-03	.1070E-08	.1185E-11	0.	0.	0.	0.
.25	.2165E-02	.3298E-03	.1067E-08	.1179E-11	.213002E-03	.324422E-04	.105007E-09	.115975E-12
.50	.1941E-02	.3249E-03	.1060E-08	.1160E-11	.806992E-03	.128670E-03	.418224E-09	.459677E-12
.75	.1624E-02	.3168E-03	.1049E-08	.1129E-11	.166657E-02	.285835E-03	.935543E-09	.102002E-11
1.00	.1277E-02	.3060E-03	.1033E-08	.1086E-11	.264664E-02	.499303E-03	.165025E-08	.177910E-11
1.25	.9544E-03	.2927E-03	.1013E-08	.1033E-11	.361693E-02	.763311E-03	.255323E-08	.271304E-11
1.50	.6861E-03	.2775E-03	.9891E-09	.9721E-12	.448972E-02	.107051E-02	.363322E-08	.379312E-11
1.75	.4804E-03	.2607E-03	.9620E-09	.9038E-12	.522412E-02	.141316E-02	.487713E-08	.498704E-11
2.00	.3306E-03	.2429E-03	.9320E-09	.8302E-12	.581400E-02	.178309E-02	.627040E-08	.626030E-11
2.25	.2246E-03	.2245E-03	.8996E-09	.7532E-12	.627211E-02	.217220E-02	.779739E-08	.757814E-11
2.50	.1512E-03	.2060E-03	.8652E-09	.6747E-12	.661905E-02	.257278E-02	.944179E-08	.890616E-11
2.75	.1021E-03	.1878E-03	.8293E-09	.5963E-12	.687784E-02	.297778E-02	.111870E-07	.102125E-10
3.00	.7030E-04	.1701E-03	.7925E-09	.5197E-12	.707096E-02	.338103E-02	.130164E-07	.114688E-10
3.25	.4986E-04	.1534E-03	.7552E-09	.4465E-12	.721743E-02	.377731E-02	.149140E-07	.126510E-10
3.50	.3613E-04	.1377E-03	.7177E-09	.3778E-12	.733073E-02	.416245E-02	.168644E-07	.137402E-10
3.75	.2628E-04	.1232E-03	.6805E-09	.3147E-12	.741910E-02	.453325E-02	.188531E-07	.147229E-10
4.00	.1921E-04	.1099E-03	.6440E-09	.2579E-12	.748797E-02	.488744E-02	.208670E-07	.155915E-10
4.25	.1454E-04	.9789E-04	.6084E-09	.2079E-12	.754241E-02	.522354E-02	.228941E-07	.163437E-10
4.50	.1173E-04	.8702E-04	.5739E-09	.1649E-12	.758742E-02	.554071E-02	.249230E-07	.169822E-10
4.75	.9889E-05	.7728E-04	.5408E-09	.1288E-12	.762660E-02	.583865E-02	.269469E-07	.175138E-10
5.00	.8230E-05	.6858E-04	.5092E-09	.9932E-13	.766121E-02	.611747E-02	.289557E-07	.179491E-10
5.25	.6575E-05	.6083E-04	.4792E-09	.7599E-13	.769092E-02	.637756E-02	.309436E-07	.183008E-10
5.50	.5229E-05	.5395E-04	.4508E-09	.5819E-13	.771578E-02	.661951E-02	.329053E-07	.185832E-10
5.75	.4466E-05	.4785E-04	.4240E-09	.4518E-13	.773715E-02	.684409E-02	.348365E-07	.188109E-10
6.00	.4154E-05	.4245E-04	.3988E-09	.3616E-13	.775703E-02	.705215E-02	.367337E-07	.189981E-10
6.25	.3881E-05	.3768E-04	.3752E-09	.3031E-13	.777634E-02	.724465E-02	.385945E-07	.191577E-10
6.50	.3368E-05	.3348E-04	.3531E-09	.2683E-13	.779446E-02	.742260E-02	.404168E-07	.193006E-10
6.75	.2719E-05	.2980E-04	.3324E-09	.2499E-13	.781027E-02	.758706E-02	.421992E-07	.194354E-10
7.00	.2246E-05	.2657E-04	.3129E-09	.2412E-13	.782365E-02	.773910E-02	.439405E-07	.195679E-10
7.25	.2107E-05	.2376E-04	.2947E-09	.2367E-13	.783582E-02	.787981E-02	.456399E-07	.197016E-10
7.50	.2130E-05	.2132E-04	.2777E-09	.2322E-13	.784809E-02	.801024E-02	.472968E-07	.198374E-10
7.75	.2031E-05	.1919E-04	.2616E-09	.2244E-13	.786055E-02	.813142E-02	.489108E-07	.199741E-10
8.00	.1697E-05	.1733E-04	.2466E-09	.2116E-13	.787207E-02	.824425E-02	.504817E-07	.201089E-10
8.25	.1349E-05	.1570E-04	.2324E-09	.1930E-13	.788177E-02	.834957E-02	.520093E-07	.202379E-10
8.50	.1190E-05	.1427E-04	.2191E-09	.1687E-13	.789011E-02	.844810E-02	.534936E-07	.203567E-10
8.75	.1194E-05	.1301E-04	.2066E-09	.1397E-13	.789818E-02	.854044E-02	.549347E-07	.204611E-10
9.00	.1277E-05	.1187E-04	.1948E-09	.1076E-13	.790680E-02	.862709E-02	.563329E-07	.205471E-10
9.25	.1220E-05	.1085E-04	.1837E-09	.7427E-14	.791575E-02	.870847E-02	.576889E-07	.206121E-10
9.50	.9945E-06	.9927E-05	.1734E-09	.4169E-14	.792389E-02	.878492E-02	.590032E-07	.206547E-10
9.75	.7528E-06	.9089E-05	.1637E-09	.1180E-14	.793048E-02	.885676E-02	.602768E-07	.206747E-10
10.00	.7128E-06	.8330E-05	.1546E-09		.793616E-02	.892427E-02	.615107E-07	.206739E-10
10.25	.7998E-06	.7646E-05	.1462E-09		.794218E-02	.898776E-02	.627062E-07	.206550E-10
10.50	.8475E-06	.7034E-05	.1383E-09		.794890E-02	.904755E-02	.638647E-07	.206222E-10
10.75	.7828E-06	.6490E-05	.1310E-09		.795570E-02	.910395E-02	.649878E-07	.205804E-10
11.00	.6016E-06	.6010E-05	.1242E-09		.796160E-02	.915731E-02	.660769E-07	.205349E-10
11.25	.4535E-06	.5587E-05	.1178E-09		.796620E-02	.920796E-02	.671330E-07	.204912E-10
11.50	.4743E-06	.5216E-05	.1120E-09		.797035E-02	.925620E-02	.681600E-07	.204544E-10
11.75	.5675E-06	.4887E-05	.1065E-09		.797511E-02	.930230E-02	.691570E-07	.204286E-10
12.00	.5952E-06	.4591E-05	.1014E-09		.798053E-02	.934648E-02	.701262E-07	.204171E-10
12.25	.4987E-06	.4322E-05	.9663E-10		.798574E-02	.938891E-02	.710689E-07	.204216E-10
12.50	.3755E-06	.4070E-05	.9216E-10		.798998E-02	.942968E-02	.719861E-07	.204428E-10
12.75	.2868E-06	.3832E-05	.8795E-10		.799326E-02	.946885E-02	.728789E-07	.204795E-10
13.00	.3210E-06	.3603E-05	.8397E-10		.799633E-02	.950643E-02	.737479E-07	.205297E-10
13.25	.4113E-06	.3383E-05	.8019E-10		.800011E-02	.954243E-02	.745938E-07	.205900E-10
13.50	.4309E-06	.3172E-05	.7659E-10		.800454E-02	.957685E-02	.754171E-07	.206563E-10
13.75	.3344E-06	.2973E-05	.7316E-10		.800863E-02	.960972E-02	.762182E-07	.207239E-10
14.00	.2257E-06	.2788E-05	.6988E-10		.801167E-02	.964110E-02	.769974E-07	.207883E-10
14.25	.2021E-06	.2619E-05	.6674E-10		.801404E-02	.967109E-02	.777551E-07	.208451E-10
14.50	.2489E-06	.2468E-05	.6375E-10		.801659E-02	.969980E-02	.784916E-07	.208906E-10

Table 4-2. (Continued)

14.75	.3256E-06	.2336E-05	.6089E-10	.801990E-02	.972738E-02	.792073E-07	.209221E-10
15.00	.3276E-06	.2221E-05	.5817E-10	.802371E-02	.975399E-02	.799027E-07	.209300E-10
15.25	.2248E-06	.2121E-05	.5560E-10	.802699E-02	.977977E-02	.805783E-07	.209377E-10
15.50	.1465E-06	.2033E-05	.5316E-10	.802922E-02	.980484E-02	.812348E-07	.209223E-10
15.75	.1522E-06	.1952E-05	.5087E-10	.803106E-02	.982929E-02	.818731E-07	.208938E-10
16.00	.2212E-06	.1876E-05	.4872E-10	.803339E-02	.985315E-02	.824938E-07	.208551E-10
16.25	.2645E-06	.1801E-05	.4671E-10	.803647E-02	.987644E-02	.830980E-07	.208101E-10
16.50	.2465E-06	.1724E-05	.4483E-10	.803975E-02	.989910E-02	.836866E-07	.207628E-10
16.75	.1645E-06	.1645E-05	.4309E-10	.804243E-02	.992110E-02	.842605E-07	.207177E-10
17.00	.9915E-07	.1565E-05	.4146E-10	.804417E-02	.994237E-02	.848207E-07	.206787E-10
17.25	.1243E-06	.1484E-05	.3993E-10	.804568E-02	.996287E-02	.853680E-07	.206493E-10
17.50	.1896E-06	.1405E-05	.3851E-10	.804782E-02	.998257E-02	.859031E-07	.206323E-10
17.75	.2163E-06	.1330E-05	.3716E-10	.805063E-02	.100015E-01	.864268E-07	.206291E-10
18.00	.1709E-06	.1263E-05	.3589E-10	.805335E-02	.100197E-01	.869395E-07	.206403E-10
18.25	.1092E-06	.1203E-05	.3467E-10	.805534E-02	.100372E-01	.874417E-07	.206654E-10
18.50	.6701E-07	.1153E-05	.3350E-10	.805661E-02	.100542E-01	.879335E-07	.207024E-10
18.75	.9523E-07	.1112E-05	.3236E-10	.805780E-02	.100708E-01	.884152E-07	.207489E-10
19.00	.1558E-06	.1078E-05	.3126E-10	.805966E-02	.100870E-01	.888868E-07	.208013E-10
19.25	.1744E-06	.1055E-05	.3018E-10	.806214E-02	.101031E-01	.893482E-07	.208550E-10
19.50	.1227E-06	.1027E-05	.2912E-10	.806440E-02	.101189E-01	.897994E-07	.209086E-10
19.75	.6266E-07	.9940E-06	.2809E-10	.806583E-02	.101345E-01	.902403E-07	.209558E-10
20.00	.5370E-07	.9652E-06	.2708E-10	.806673E-02	.101498E-01	.906708E-07	.209941E-10
20.25	.8741E-07	.9308E-06	.2610E-10	.806785E-02	.101647E-01	.910911E-07	.210209E-10
20.50	.1395E-06	.8969E-06	.2515E-10	.806967E-02	.101794E-01	.915011E-07	.210347E-10
20.75	.1453E-06	.8518E-06	.2423E-10	.807198E-02	.101935E-01	.919010E-07	.210347E-10
21.00	.8538E-07	.8111E-06	.2336E-10	.807386E-02	.102072E-01	.922911E-07	.210215E-10
21.25	.3954E-07	.7766E-06	.2253E-10	.807490E-02	.102203E-01	.926718E-07	.209965E-10
21.50	.4650E-07	.7338E-06	.2176E-10	.807562E-02	.102330E-01	.930436E-07	.209621E-10
21.75	.9394E-07	.7018E-06	.2103E-10	.807682E-02	.102452E-01	.934069E-07	.209214E-10
22.00	.1248E-06	.6740E-06	.2035E-10	.807870E-02	.102570E-01	.937623E-07	.208779E-10
22.25	.1166E-06	.6531E-06	.1972E-10	.808079E-02	.102685E-01	.941105E-07	.208354E-10
22.50	.6654E-07	.6374E-06	.1914E-10	.808240E-02	.102799E-01	.944520E-07	.207974E-10
22.75	.2637E-07	.6191E-06	.1860E-10	.808322E-02	.102910E-01	.947873E-07	.207671E-10
23.00	.4442E-07	.6139E-06	.1810E-10	.808386E-02	.103021E-01	.951170E-07	.207472E-10
23.25	.8985E-07	.6043E-06	.1763E-10	.808508E-02	.103132E-01	.954414E-07	.207392E-10
23.50	.1102E-06	.5897E-06	.1717E-10	.808692E-02	.103241E-01	.957608E-07	.207440E-10
23.75	.8251E-07	.5781E-06	.1674E-10	.808871E-02	.103350E-01	.960755E-07	.207613E-10
24.00	.4315E-07	.5610E-06	.1632E-10	.808988E-02	.103456E-01	.963854E-07	.207898E-10
24.25	.1617E-07	.5436E-06	.1590E-10	.809044E-02	.103561E-01	.966905E-07	.208276E-10
24.50	.3630E-07	.5171E-06	.1548E-10	.809095E-02	.103663E-01	.969900E-07	.208716E-10
24.75	.7885E-07	.4932E-06	.1506E-10	.809206E-02	.103760E-01	.972860E-07	.209188E-10
25.00	.9382E-07	.4738E-06	.1463E-10	.809375E-02	.103855E-01	.975760E-07	.209655E-10
25.25	.6024E-07	.4472E-06	.1421E-10	.809527E-02	.103946E-01	.978605E-07	.210084E-10
25.50	.2007E-07	.4288E-06	.1378E-10	.809607E-02	.104033E-01	.981394E-07	.210444E-10
25.75	.1127E-07	.4135E-06	.1336E-10	.809638E-02	.104118E-01	.984125E-07	.210708E-10
26.00	.3874E-07	.4031E-06	.1294E-10	.809689E-02	.104201E-01	.986797E-07	.210860E-10
26.25	.7616E-07	.3965E-06	.1253E-10	.809807E-02	.104283E-01	.989411E-07	.210890E-10
26.50	.8203E-07	.3877E-06	.1214E-10	.809971E-02	.104364E-01	.991966E-07	.210799E-10
26.75	.4156E-07	.3890E-06	.1177E-10	.810100E-02	.104445E-01	.994467E-07	.210598E-10
27.00	.9858E-08	.3865E-06	.1142E-10	.810154E-02	.104527E-01	.996914E-07	.210304E-10
27.25	.1504E-07	.3796E-06	.1109E-10	.810181E-02	.104609E-01	.999312E-07	.209944E-10
27.50	.4936E-07	.3751E-06	.1079E-10	.810250E-02	.104690E-01	.100166E-06	.209547E-10
27.75	.7232E-07	.3657E-06	.1052E-10	.810382E-02	.104770E-01	.100398E-06	.209148E-10
28.00	.6804E-07	.3558E-06	.1027E-10	.810536E-02	.104849E-01	.100625E-06	.208778E-10
28.25	.3339E-07	.3384E-06	.1004E-10	.810648E-02	.104926E-01	.100849E-06	.208469E-10
28.50	.4927E-08	.3227E-06	.9832E-11	.810690E-02	.104999E-01	.101071E-06	.208246E-10
28.75	.1770E-07	.3106E-06	.9639E-11	.810716E-02	.105071E-01	.101290E-06	.208127E-10
29.00	.4485E-07	.2922E-06	.9489E-11	.810787E-02	.105139E-01	.101507E-06	.208164E-10
29.25	.6737E-07	.2803E-06	.9307E-11	.810915E-02	.105204E-01	.101722E-06	.208352E-10
29.50	.5471E-07	.2711E-06	.9094E-11	.811056E-02	.105268E-01	.101934E-06	.208606E-10

Table 4-2. (Continued)

29.75	.2052E-07	.2640E-06	.8917E-11	.811143E-02	.105330E-01	.102143E-06	.208913E-10
30.00	.1130E-08	.2628E-06	.8736E-11	.811169E-02	.105392E-01	.102350E-06	.209295E-10
30.25	.1623E-07	.2583E-06	.8538E-11	.811189E-02	.105454E-01	.102555E-06	.209711E-10
30.50	.4821E-07	.2588E-06	.8333E-11	.811266E-02	.105515E-01	.102756E-06	.210112E-10
30.75	.6188E-07	.2626E-06	.8142E-11	.811399E-02	.105578E-01	.102954E-06	.210499E-10
31.00	.4245E-07	.2594E-06	.7933E-11	.811525E-02	.105641E-01	.103149E-06	.210853E-10
31.25	.1087E-07	.2578E-06	.7682E-11	.811590E-02	.105705E-01	.103340E-06	.211089E-10
31.50	.6141E-09	.2527E-06	.7466E-11	.811604E-02	.105767E-01	.103527E-06	.211186E-10
31.75	.2162E-07	.2465E-06	.7286E-11	.811632E-02	.105829E-01	.103710E-06	.211217E-10
32.00	.5021E-07	.2374E-06	.7079E-11	.811722E-02	.105890E-01	.103890E-06	.211181E-10
32.25	.5517E-07	.2230E-06	.6852E-11	.811855E-02	.105948E-01	.104065E-06	.211009E-10
32.50	.3123E-07	.2148E-06	.6673E-11	.811965E-02	.106004E-01	.104237E-06	.210723E-10
32.75	.4172E-08	.2038E-06	.6508E-11	.812010E-02	.106057E-01	.104406E-06	.210385E-10
33.00	.2553E-08	.1928E-06	.6354E-11	.812019E-02	.106109E-01	.104572E-06	.210019E-10
33.25	.2713E-07	.1867E-06	.6212E-11	.812057E-02	.106158E-01	.104736E-06	.209645E-10
33.50	.5066E-07	.1822E-06	.6101E-11	.812159E-02	.106206E-01	.104897E-06	.209307E-10
33.75	.4760E-07	.1826E-06	.5997E-11	.812289E-02	.106254E-01	.105057E-06	.209042E-10
34.00	.2142E-07	.1804E-06	.5869E-11	.812381E-02	.106303E-01	.105215E-06	.208819E-10
34.25	.2403E-09	.1822E-06	.5781E-11	.812410E-02	.106351E-01	.105371E-06	.208651E-10
34.50	.6275E-08	.1868E-06	.5728E-11	.812418E-02	.106401E-01	.105526E-06	.208623E-10
34.75	.3217E-07	.1855E-06	.5649E-11	.812471E-02	.106452E-01	.105681E-06	.208739E-10
35.00	.4950E-07	.1855E-06	.5569E-11	.812583E-02	.106503E-01	.105834E-06	.208951E-10
35.25	.3959E-07	.1825E-06	.5464E-11	.812706E-02	.106553E-01	.105987E-06	.209217E-10
35.50	.1330E-07	.1785E-06	.5381E-11	.812779E-02	.106603E-01	.106137E-06	.209528E-10
35.75		.1719E-06	.5289E-11	.812796E-02	.106652E-01	.106286E-06	.209892E-10
36.00		.1608E-06	.5184E-11	.812810E-02	.106699E-01	.106434E-06	.210272E-10
36.25		.1549E-06	.5084E-11	.812877E-02	.106744E-01	.106580E-06	.210647E-10
36.50		.1465E-06	.4971E-11	.812996E-02	.106787E-01	.106723E-06	.211000E-10
36.75		.1379E-06	.4852E-11	.813109E-02	.106828E-01	.106865E-06	.211296E-10
37.00		.1337E-06	.4699E-11	.813165E-02	.106867E-01	.107003E-06	.211473E-10
37.25		.1306E-06	.4574E-11	.813175E-02	.106906E-01	.107138E-06	.211515E-10
37.50		.1317E-06	.4476E-11	.813198E-02	.106944E-01	.107271E-06	.211495E-10
37.75		.1307E-06	.4356E-11	.813281E-02	.106983E-01	.107401E-06	.211414E-10
38.00		.1330E-06	.4223E-11	.813403E-02	.107022E-01	.107529E-06	.211215E-10
38.25		.1378E-06	.4123E-11	.813503E-02	.107063E-01	.107654E-06	.210921E-10
38.50		.1374E-06	.4036E-11	.813544E-02	.107104E-01	.107777E-06	.210594E-10
38.75		.1382E-06	.3952E-11	.813551E-02	.107146E-01	.107898E-06	.210249E-10
39.00		.1366E-06	.3879E-11	.813588E-02	.107188E-01	.108018E-06	.209899E-10
39.25		.1338E-06	.3832E-11	.813684E-02	.107230E-01	.108136E-06	.209598E-10
39.50		.1289E-06	.3786E-11	.813806E-02	.107270E-01	.108254E-06	.209379E-10
39.75		.1200E-06	.3718E-11	.813892E-02	.107309E-01	.108371E-06	.209204E-10
40.00		.1155E-06	.3681E-11	.813920E-02	.107346E-01	.108486E-06	.209083E-10

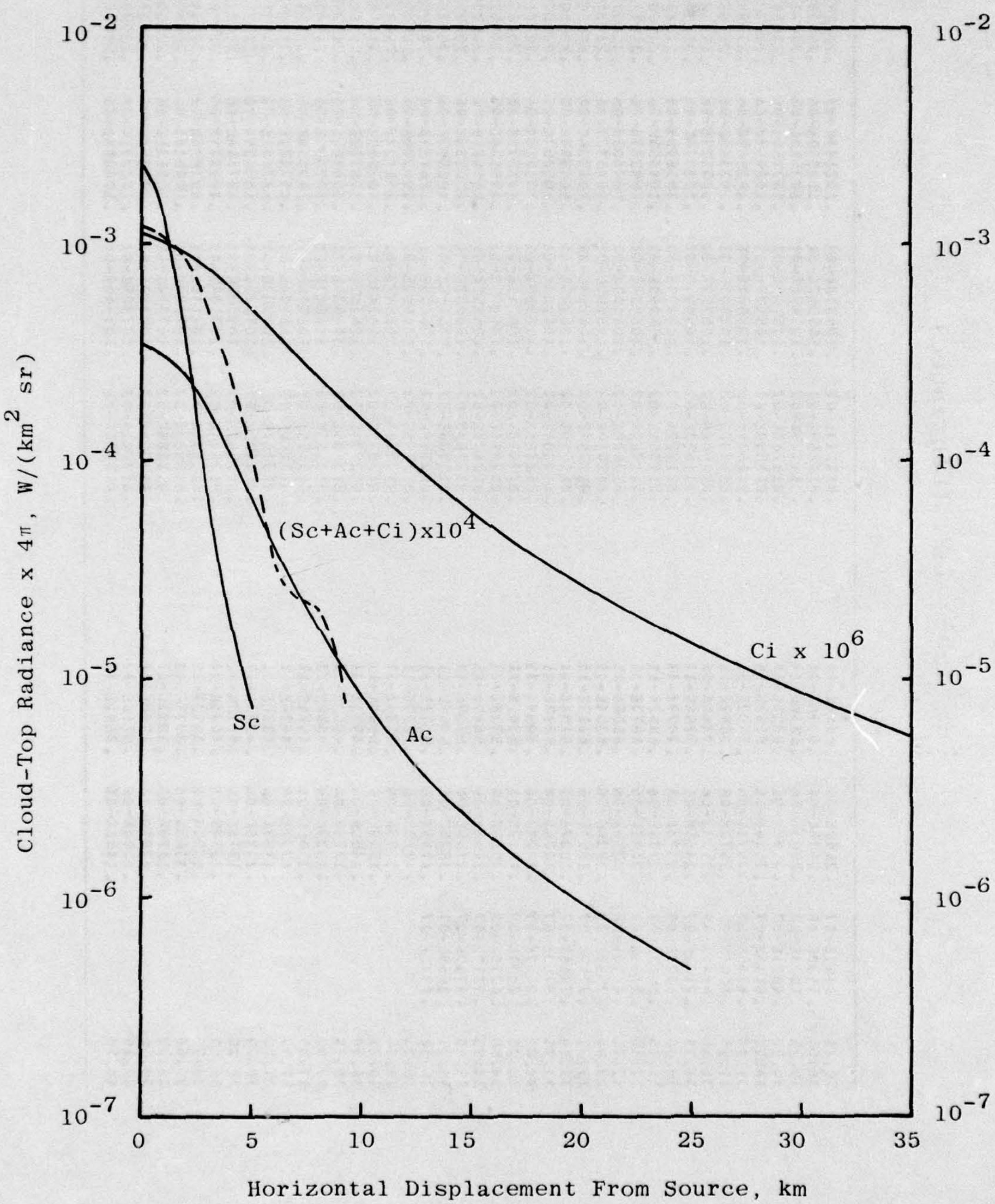

Figure 4-3. Output for sample Problems 1 to 4

where

T_i = transmittance of ith layer

R_i = reflectance of ith layer.

The total reflectance R for a planar slab is given by Equation (31b) of Appendix A as

$$R = T \cdot \tfrac{1}{2} \left(\frac{a}{Kb} - \frac{Kb}{a} \right) \sinh KL \quad .$$

We can now compare our code results with the analytical results. This comparison is given in Table 4-3 where we give, as a function of the lateral displacement from the source, the ratio of the code-computed integrated-transmittance to the analytic integrated-transmittance. We see that for cloud Sc the code result is less than the analytic result by only 7%, 3%, and 2% at distances of 5, 10, and 15 km. For cloud Ac and cloud Ci the code results are small by 5% and 15% even at 40 km. For the three-layer configuration, the code result is small by only 15% at 5 km and 2% at 10 km.

We conclude that, whereas the comparisons between the code results and the analytic results for the integrated transmittance are not perfect for these examples, the comparison is of sufficiently high quality for the radial distances of importance that one can have a high confidence in the diffusion calculations performed in the statistical cloud submodel.

We return now to the input cards for Problems 1 to 4. We have two general choices for KMODEL which can be either (a) any value in the range from 1 to 10 or (b) a value of 11.

If KMODEL is less than 11, it doesn't matter, for Problems 1 to 4, which of the allowed values we choose. We can understand that fact by reviewing how the code operates for, say, Problem 1:

(1) ROSCOER reads the detector, source, and wavelength cards.

(2) Subroutine CLOUDO reads the Type-1 and Type-2 cards and three Type-2d cards.

(2.1) On the Type-2 card we set KCOVER and KLAYER to 0 since we have no need to override the stored data for either the CCOVER or CFREQ arrays; in fact, we really don't use the stored data for these arrays.

Table 4-3. Ratio of T(code)- to T(analytic)-results for sample Problems 1 to 4.

Distance (km)	Cloud Configuration Sc	Ac	Ci	Sc + Ac + Ci
5	0.934	0.543	0.228	0.850
10	0.968	0.792	0.485	0.979
15	0.978	0.866	0.630	
20		0.901	0.714	
25		0.922	0.769	
30		0.936	0.806	
35		0.946	0.834	
40		0.953	0.855	

(2.2) On the Type-2 card we set KTYPL, KTYPM, and KTYPH to 1 to allow the code to read in three Type-2d cards.

(3) The three Type-2d cards specify that the only cloud configuration of interest is that for which the low-altitude layer has cloud Type-4 (Sc) and the mid- and high-altitude layers are clear.

(4) ROSCOER calls subroutine SCLOUD.

(5) Subroutine SCLOUD calls subroutine CLDWT.

(6) Subroutine CLDWT's calculations are very much restricted compared with a normal run.

(6.1) Consider Pass-1 through the DO-500 loop (II=2). In the DO-101 loop, the tests are satisfied only for LL=4. PIJKL is computed and IDX is set to 1. TRANS(1) and WT(160) are also computed (but never used). None of the loops after DO-101 becomes effective.

(6.2) Consider Pass-2 through the DO-500 loop (II=3). Again, in DO-101 loop, tests are satisfied only for LL=4. PIJKL is computed and IDX is again set to 1. This time, computations of TRANS(1) and EMISS(1) are skipped because they were computed on Pass-1. The Pass-1 values of WT(1) and WT(160) are augmented with the Pass-2 values (but, again, will never be used).

(6.3) Pass-3 and Pass-4 through DO-500 loop are just like Pass-2.

(6.4) Subroutine CLDWT returns to subroutine SCLOUD values for TRANS(1), EMISS(1), WT(1), and WT(2) = WT(160).

(7.1) In subroutine SCLOUD we exploit common PTE by arbitrarily setting T4 equal to TRANS(1), the modified transfer coefficient.

(7.2) The code effectively returns to ROSCOER without doing any of the usual calculations or sorting in subroutine SCLOUD.

(8) ROSCOER then performs the radial integration over the cloud-top surface.

We now consider what would happen if we inputted 11 for KMODEL. First, we note that the code would expect to read a Type-2a card and four Type-2b cards. The natural selection of values for these cards would be as follows:

For Problems 1 to 4:

$$\text{CCOVER (I,11)} = \begin{cases} 0.0, & I=1,4 \\ 1.0, & I=5 \end{cases}$$

$$\text{CFREQ(I,J,11)} = 0.0 \text{ (I=1,17), J=1,3}$$

and

$$\text{CFREQ(I,4,11)} = \begin{cases} \left.\begin{array}{l} 1.0 \text{ I=4 \& 15} \\ 0.0 \text{ Otherwise} \end{array}\right\} & 1 \\ \left.\begin{array}{l} 1.0 \text{ I=8 \& 15} \\ 0.0 \text{ Otherwise} \end{array}\right\} & 2 \\ \left.\begin{array}{l} 1.0 \text{ I=13 \& 15} \\ 0.0 \text{ Otherwise} \end{array}\right\} & 3 \\ \left.\begin{array}{l} 1.0 \text{ I=4,8,13 \& 17} \\ 0.0 \text{ Otherwise} \end{array}\right\} & 4 \end{cases} \quad \underline{\text{Problem}}$$

However, it really wouldn't matter what is read in for CCOVER and CFREQ since we do not use them in Problems 1 to 4.

Subroutine CLDWT will return the complete arrays for TRANS and EMISS but the WT array will have zeros except that:

WT(4)≠0 and WT(160)≠0 for Problem 1
WT(8)≠0 and WT(160)≠0 for Problem 2
WT(13)≠0 and WT(160)≠0 for Problem 3
WT(114)≠0 and WT(160)≠0 for Problem 4

Of course, we are interested in TRANS(IDX) for selected values of IDX: i.e., IDX = 4,8,13, and 114 for Problems 1,2,3, and 4, respectively. These members of the TRANS array can and should be intercepted in subroutine SCLOUD immediately after the return from subroutine SCLOUD immediately after the return from subroutine CLDWT. Failure to intercept at this point would allow the TRANS array to be sorted, with the loss of identity of the particular member of TRANS that is of interest.

4-3.2 Problem 5: Use of the statistical cloud submodel in the optional mode with KMODEL=11

The purpose of this problem is the illustrate (1) use of the statistical cloud submodel in the optional mode with KMODEL=11 and (2) a detailed printout of the complete results for a statistical cloud problem.

Use of the cloud model with KMODEL=11 requires the user to read in the Type-2a card for (CCOVER(I,11), I=1,5) and four Type-2b cards for (CFREQ(I,J,11), I=1,17; J=1,4), as seen from Figure 4-1. The input data deck is shown in Figure 4-4.

Selection of appropriate data for use with KMODEL=11, i.e., for the CCOVER and CFREQ arrays, is always the user's responsibility. For the authors' convenience, and for illustration, we have arbitrarily selected the data from that given for KMODEL=1, as can be seen by comparing with BLOCK DATA. (In this instance, because we have used data from KMODEL=1, we could get the same results more directly by not inputting 11 for KMODEL and the associated Type-2a and Type-2b cards but instead inputting 1 for KMODEL.)

Because we have inputted a 1 for the source-type flag ISUN, the code will first do the problem with the artificial source as specified and then do the problem with the sun as the source. The emission radiance will be calculated in each case.

The output results for the artificial source are shown in Tables 4-4a through 4-4d and those for the solar source are shown in Table 4-5a thorugh 4-5c.

The quantities in the various columns in Tables 4-4a and 4-5a are described in Table 4-6. The results for IDX=1,159 are provided by subroutine CLDWT for the 159 different cloud configurations. The entries for TRANS≡TCOEF with values of $\sim 10^{-51}$ occur when the argument of the sinh and cosh functions in the integral being evaluated

```
******************* PROBLEM 5  ************************************
    HD        THETAD      PHID       FOV                 DETECTOR
  35793.     90.00001   -90.0001    1.0
 HSOURCE(1) THETAS(1)   PHIS(1)     WKT                  SOURCE
   0.01     90.000001   -90.00      1000.
      ISUN
         1
   ALAM                                                  WAVELENGTH
   2.50
      MODE                                               STATISTICAL        CARD 1
         1
KMODEL        KLAYER     KTYPM                           USER CLOUD MODEL   CARD 2
      KCOVER       KTYPL       KTYPH
   11     0     0     0     0     0
I=1 I=2 I=3 I=4 I=5                                      CCOVER(I,11)       CARD 2A
.235.150.070.201.343
                                                         CFREQ(I,1,11)      CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.046.046.046.102.006.005.001.217.005.005.005.005.222.293.766.212.019
                                                         CFREQ(I,2,11)      CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.055.055.055.121.006.008.001.243.009.008.008.009.164.260.542.377.081
                                                         CFREQ(I,3,11)      CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.038.038.038.169.015.010.000.276.012.010.010.012.104.266.415.435.150
                                                         CFREQ(I,4,11)      CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.010.010.010.336.155.010.030.197.023.010.010.023.017.158.448.423.128
```

Figure 4-4. Input data for Problem 5.

Table 4-4a. Initial arrays for artificial source transfer-coefficients, emission radiances, and weights in sample Problem 5. Wavelength = 2.5 µm.

IDX	LL	MM	HH	TRANS	EMISS	CC=2	CC=3	CC=4	CC=5	WT	WT(SUM)
1	1			.3798E+01	.2553E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.4231E-02
2	2			.8990E-08	.1473E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.8462E-02
3	3			.1276E+00	.1208E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.1269E-01
4	4			.4617E-01	.2227E+03	.1528E-02	.1056E-02	.7331E-02	.4750E-01	.5741E-01	.7011E-01
5	5			.1158E+00	.2529E+03	.8986E-04	.5236E-04	.6506E-03	.2191E-01	.2271E-01	.9281E-01
6	6			.3798E+01	.2553E+03	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.9480E-01
7	7			.4801E-02	.1473E+03	.1498E-04	.8726E-05	0.	.4241E-02	.4265E-02	.9907E-01
8		1		.6812E-02	.6389E+02	.3250E-02	.2120E-02	.1197E-01	.2785E-01	.4519E-01	.1443E+00
9		2		.4550E-05	.6389E+02	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1482E+00
10		3		.6135E-37	.6389E+02	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1502E+00
11			1	.1160E-06	.1126E+01	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1522E+00
12			2	.4365E-51	.5296E+01	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1561E+00
13			3	.2199E-07	.1073E+02	.3325E-02	.1431E-02	.4511E-02	.2403E-02	.1167E-01	.1678E+00
14			4	.1826E-23	.5296E+01	.4388E-02	.2269E-02	.1154E-01	.2234E-01	.4053E-01	.2083E+00
15	1	1		.6281E-02	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2110E+00
16	1	2		.5278E-05	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2112E+00
17	1	3		.4506E-37	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2113E+00
18	2	1		.8333E-10	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2140E+00
19	2	2		.7280E-51	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2142E+00
20	2	3		.7280E-51	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2143E+00
21	3	1		.1901E-02	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2171E+00
22	3	2		.8300E-06	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2172E+00
23	3	3		.3597E-38	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2173E+00
24	4	1		.2231E-03	.6389E+02	.2964E-03	.5480E-03	.6439E-02	.3010E-01	.3738E-01	.2547E+00
25	4	2		.1553E-06	.6389E+02	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2585E+00
26	4	3		.7280E-51	.6389E+02	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2603E+00
27	5	1		.9948E-04	.6389E+02	.1744E-04	.2717E-04	.5715E-03	.1388E-01	.1450E-01	.2748E+00
28	5	2		.8970E-07	.6389E+02	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.2765E+00
29	5	3		.7280E-51	.6389E+02	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.2772E+00
30	6	1		.6281E-02	.6389E+02	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.2785E+00
31	6	2		.5278E-05	.6389E+02	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.2787E+00
32	6	3		.4506E-37	.6389E+02	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.2787E+00
33	7	1		.6474E-04	.6389E+02	.2906E-05	.4529E-05	0.	.2687E-02	.2695E-02	.2814E+00
34	7	2		.3119E-07	.6389E+02	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.2817E+00
35	7	3		.7280E-51	.6389E+02	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.2819E+00
36	1		1	.4614E-06	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2820E+00
37	1		2	.4365E-51	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2822E+00
38	1		3	.6192E-07	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2831E+00
39	1		4	.7354E-23	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2856E+00
40	2		1	.3637E-51	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2858E+00
41	2		2	.4365E-51	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2859E+00
42	2		3	.4851E-51	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2869E+00
43	2		4	.4365E-51	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2894E+00
44	3		1	.1482E-06	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2895E+00
45	3		2	.4365E-51	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2897E+00
46	3		3	.1384E-07	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2906E+00
47	3		4	.1200E-23	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2932E+00
48	4		1	.1033E-07	.1126E+01	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2950E+00
49	4		2	.4365E-51	.5296E+01	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2988E+00
50	4		3	.1491E-08	.1073E+02	.3033E-03	.3699E-03	.2426E-02	.2597E-02	.5697E-02	.3045E+00
51	4		4	.4355E-51	.5296E+01	.4002E-03	.5864E-03	.6206E-02	.2414E-01	.3133E-01	.3358E+00
52	5		1	.5835E-08	.1126E+01	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.3366E+00
53	5		2	.4365E-51	.5296E+01	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.3382E+00
54	5		3	.8534E-09	.1073E+02	.1784E-04	.1834E-04	.2154E-03	.1198E-02	.1450E-02	.3397E+00
55	5		4	.4365E-51	.5296E+01	.2354E-04	.2908E-04	.5508E-03	.1114E-01	.1174E-01	.3514E+00
56	6		1	.4614E-06	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3515E+00
57	6		2	.4365E-51	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3516E+00
58	6		3	.6192E-07	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3518E+00
59	6		4	.7354E-23	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3530E+00

Table 4-4a. (Continued)

60	7		1	.3062E-08	.1126E+01	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.3531E+00
61	7		2	.4355E-51	.5296E+01	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.3534E+00
62	7		3	.3234E-09	.1073E+02	.2973E-05	.3057E-05	0.	.2319E-03	.2379E-03	.3537E+00
63	7		4	.4365E-51	.5296E+01	.3924E-05	.4846E-05	0.	.2155E-02	.2164E-02	.3558E+00
64		1	1	.8740E-08	.1126E+01	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.3572E+00
65		1	2	.4365E-51	.5296E+01	.1453E-04	.4076E-04	.4572E-03	.2060E-02	.2573E-02	.3597E+00
66		1	3	.8132E-09	.1073E+02	.6452E-03	.7428E-03	.3963E-02	.1523E-02	.6873E-02	.3666E+00
67		1	4	.4365E-51	.5296E+01	.8515E-03	.1178E-02	.1014E-01	.1415E-01	.2632E-01	.3929E+00
68		2	1	.3637E-51	.1126E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3931E+00
69		2	2	.4355E-51	.5296E+01	.3348E-06	.1510E-05	.1988E-04	.2405E-03	.2623E-03	.3933E+00
70		2	3	.4851E-51	.1073E+02	.1487E-04	.2751E-04	.1723E-03	.1778E-03	.3925E-03	.3937E+00
71		2	4	.4365E-51	.5296E+01	.1962E-04	.4361E-04	.4407E-03	.1652E-02	.2156E-02	.3959E+00
72		3	1	.3637E-51	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3959E+00
73		3	2	.4365E-51	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3960E+00
74		3	3	.4851E-51	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3963E+00
75		3	4	.4365E-51	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3974E+00
76	1	1	1	.7693E-08	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.3975E+00
77	1	1	2	.4365E-51	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.3977E+00
78	1	1	3	.7393E-09	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.3983E+00
79	1	1	4	.4365E-51	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4001E+00
80	1	2	1	.3705E-11	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4002E+00
81	1	2	2	.4365E-51	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4002E+00
82	1	2	3	.1339E-12	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4002E+00
83	1	2	4	.4365E-51	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4003E+00
84	1	3	1	.3637E-51	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4003E+00
85	1	3	2	.4355E-51	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4003E+00
86	1	3	3	.4851E-51	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4003E+00
87	1	3	4	.4365E-51	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4004E+00
88	2	1	1	.3637E-51	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4005E+00
89	2	1	2	.4365E-51	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4006E+00
90	2	1	3	.4851E-51	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4013E+00
91	2	1	4	.4365E-51	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4031E+00
92	2	2	1	.3637E-51	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4031E+00
93	2	2	2	.4355E-51	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4031E+00
94	2	2	3	.4851E-51	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4032E+00
95	2	2	4	.4365E-51	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4033E+00
96	2	3	1	.3637E-51	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4033E+00
97	2	3	2	.4365E-51	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4033E+00
98	2	3	3	.4851E-51	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4033E+00
99	2	3	4	.4365E-51	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4034E+00
100	3	1	1	.2590E-08	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4035E+00
101	3	1	2	.4355E-51	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4036E+00
102	3	1	3	.2307E-09	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4042E+00
103	3	1	4	.4365E-51	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4061E+00
104	3	2	1	.3637E-51	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4061E+00
105	3	2	2	.4365E-51	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4061E+00
106	3	2	3	.4851E-51	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4061E+00
107	3	2	4	.4365E-51	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4062E+00
108	3	3	1	.3637E-51	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4062E+00
109	3	3	2	.4355E-51	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4062E+00
110	3	3	3	.4851E-51	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4063E+00
111	3	3	4	.4365E-51	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4063E+00
112	4	1	1	.3637E-51	.1126E+01	.1365E-05	.8888E-05	.2033E-03	.9962E-03	.1210E-02	.4075E+00
113	4	1	2	.4365E-51	.5296E+01	.1365E-05	.9999E-05	.2439E-03	.2291E-02	.2547E-02	.4101E+00
114	4	1	3	.4851E-51	.1073E+02	.6062E-04	.1822E-03	.2114E-02	.1694E-02	.4050E-02	.4141E+00
115	4	1	4	.4365E-51	.5296E+01	.8001E-04	.2889E-03	.5406E-02	.1574E-01	.2152E-01	.4357E+00
116	4	2	1	.3637E-51	.1126E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4358E+00
117	4	2	2	.4355E-51	.5296E+01	.3146E-07	.3703E-06	.1060E-04	.2675E-03	.2785E-03	.4361E+00
118	4	2	3	.4851E-51	.1073E+02	.1397E-05	.6748E-05	.9190E-04	.1977E-03	.2978E-03	.4364E+00
119	4	2	4	.4365E-51	.5296E+01	.1843E-05	.1070E-04	.2351E-03	.1838E-02	.2085E-02	.4384E+00

Table 4-4a. (Continued)

120	4	3	1	.3637E-51	.1126E+01	.3146E-07	.2926E-06	.7364E-05	.5057E-04	.5826E-04	.4385E+00
121	4	3	2	.4365E-51	.5296E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4386E+00
122	4	3	3	.4851E-51	.1073E+02	.1397E-05	.5999E-05	.7659E-04	.8597E-04	.1699E-03	.4388E+00
123	4	3	4	.4365E-51	.5296E+01	.1843E-05	.9510E-05	.1959E-03	.7990E-03	.1006E-02	.4398E+00
124	5	1	1	.3637E-51	.1126E+01	.8031E-07	.4407E-06	.1804E-04	.4596E-03	.4781E-03	.4403E+00
125	5	1	2	.4365E-51	.5296E+01	.8031E-07	.4958E-06	.2165E-04	.1057E-02	.1079E-02	.4414E+00
126	5	1	3	.4851E-51	.1073E+02	.3566E-05	.9035E-05	.1876E-03	.7812E-03	.9815E-03	.4423E+00
127	5	1	4	.4365E-51	.5296E+01	.4706E-05	.1432E-04	.4799E-03	.7261E-02	.7760E-02	.4501E+00
128	5	2	1	.3637E-51	.1126E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4502E+00
129	5	2	2	.4365E-51	.5296E+01	.1851E-08	.1836E-07	.9412E-06	.1234E-03	.1244E-03	.4503E+00
130	5	2	3	.4851E-51	.1073E+02	.8216E-07	.3346E-06	.8157E-05	.9121E-04	.9978E-04	.4504E+00
131	5	2	4	.4365E-51	.5296E+01	.1084E-06	.5305E-06	.2086E-04	.8477E-03	.8692E-03	.4512E+00
132	5	3	1	.3637E-51	.1126E+01	.1851E-08	.1451E-07	.6536E-06	.2333E-04	.2400E-04	.4513E+00
133	5	3	2	.4365E-51	.5296E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4513E+00
134	5	3	3	.4851E-51	.1073E+02	.8216E-07	.2975E-06	.6798E-05	.3966E-04	.4683E-04	.4514E+00
135	5	3	4	.4365E-51	.5296E+01	.1084E-06	.4716E-06	.1739E-04	.3686E-03	.3865E-03	.4518E+00
136	6	1	1	.7693E-08	.1126E+01	.6693E-07	.5876E-06	.1203E-04	.2965E-04	.4233E-04	.4518E+00
137	6	1	2	.4365E-51	.5296E+01	.6693E-07	.6611E-06	.1443E-04	.6819E-04	.8335E-04	.4519E+00
138	6	1	3	.7393E-09	.1073E+02	.2972E-05	.1205E-04	.1251E-03	.5040E-04	.1905E-03	.4521E+00
139	6	1	4	.4365E-51	.5296E+01	.3922E-05	.1910E-04	.3199E-03	.4684E-03	.8114E-03	.4529E+00
140	6	2	1	.3705E-11	.1126E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4529E+00
141	6	2	2	.4365E-51	.5296E+01	.1542E-08	.2449E-07	.6275E-06	.7961E-05	.8615E-05	.4529E+00
142	6	2	3	.1339E-12	.1073E+02	.6847E-07	.4462E-06	.5438E-05	.5885E-05	.1184E-04	.4529E+00
143	6	2	4	.4365E-51	.5296E+01	.9037E-07	.7074E-06	.1391E-04	.5469E-04	.6940E-04	.4530E+00
144	6	3	1	.3637E-51	.1126E+01	.1542E-08	.1935E-07	.4358E-06	.1505E-05	.1962E-05	.4530E+00
145	6	3	2	.4365E-51	.5296E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4530E+00
146	6	3	3	.4851E-51	.1073E+02	.6847E-07	.3966E-06	.4532E-05	.2559E-05	.7555E-05	.4530E+00
147	6	3	4	.4365E-51	.5296E+01	.9037E-07	.6288E-06	.1159E-04	.2378E-04	.3609E-04	.4530E+00
148	7	1	1	.3637E-51	.1126E+01	.1339E-07	.7346E-07	0.	.8895E-04	.8903E-04	.4531E+00
149	7	1	2	.4365E-51	.5296E+01	.1339E-07	.8264E-07	0.	.2046E-03	.2047E-03	.4533E+00
150	7	1	3	.4851E-51	.1073E+02	.5943E-06	.1506E-05	0.	.1512E-03	.1533E-03	.4535E+00
151	7	1	4	.4365E-51	.5296E+01	.7844E-06	.2387E-05	0.	.1405E-02	.1409E-02	.4549E+00
152	7	2	1	.3637E-51	.1126E+01	.3084E-09	.2721E-08	0.	.1038E-04	.1039E-04	.4549E+00
153	7	2	2	.4365E-51	.5296E+01	.3084E-09	.3061E-08	0.	.2388E-04	.2389E-04	.4549E+00
154	7	2	3	.4851E-51	.1073E+02	.1369E-07	.5577E-07	0.	.1765E-04	.1772E-04	.4549E+00
155	7	2	4	.4365E-51	.5296E+01	.1807E-07	.8842E-07	0.	.1641E-03	.1642E-03	.4551E+00
156	7	3	1	.3637E-51	.1126E+01	.3084E-09	.2418E-08	0.	.4515E-05	.4518E-05	.4551E+00
157	7	3	2	.4365E-51	.5296E+01	.3084E-09	.2721E-08	0.	.1038E-04	.1039E-04	.4551E+00
158	7	3	3	.4851E-51	.1073E+02	.1369E-07	.4958E-07	0.	.7676E-05	.7739E-05	.4551E+00
159	7	3	4	.4365E-51	.5296E+01	.1807E-07	.7860E-07	0.	.7134E-04	.7143E-04	.4552E+00
160************				0.	0.	-R	-R	-R	-R	.5435E+00	.9987E+00

IDX = 160 TRANS(160) = .1816E+01 EMISS(160) = .3275E+03 WT (160) = .5399E+00

Table 4-4b. Sorted array for artificial source transfer-coefficients (and carried-along weights) for sample Problem 5.

TRANS,WT =

0.	0.	.3637E-51	.5612E-05	.3637E-51	.8001E-04	.3637E-51	.3308E-05
.3637E-51	.1092E-03	.3637E-51	.3308E-05	.3637E-51	.6080E-04	.3637E-51	.3308E-05
.3637E-51	.5612E-05	.3637E-51	.2400E-04	.3637E-51	.4518E-05	.3637E-51	.4781E-03
.3637E-51	.5446E-04	.3637E-51	.1228E-03	.3637E-51	.1039E-04	.3637E-51	.1962E-05
.3637E-51	.8903E-04	.3637E-51	.5826E-04	.3637E-51	.1255E-03	.3637E-51	.1210E-02
.4365E-51	.5612E-05	.4365E-51	.1132E-03	.4365E-51	.1851E-02	.4365E-51	.1282E-03
.4365E-51	.1053E-04	.4365E-51	.1282E-03	.4365E-51	.7298E-04	.4365E-51	.1132E-03
.4365E-51	.7298E-04	.4365E-51	.1144E-02	.4365E-51	.7298E-04	.4365E-51	.5612E-05
.4365E-51	.1053E-04	.4365E-51	.5612E-05	.4365E-51	.1798E-03	.4365E-51	.1798E-03
.4365E-51	.1132E-03	.4365E-51	.1851E-02	.4365E-51	.1851E-02	.4365E-51	.3865E-03
.4365E-51	.8692E-03	.4365E-51	.1798E-03	.4365E-51	.1228E-03	.4365E-51	.1244E-03
.4365E-51	.2573E-02	.4365E-51	.3140E-03	.4365E-51	.7760E-02	.4365E-51	.2561E-02
.4365E-51	.8114E-03	.4365E-51	.1642E-03	.4365E-51	.2156E-02	.4365E-51	.3925E-02
.4365E-51	.5446E-04	.4365E-51	.2623E-03	.4365E-51	.1079E-02	.4365E-51	.1053E-04
.4365E-51	.1228E-03	.4365E-51	.2164E-02	.4365E-51	.7143E-04	.4365E-51	.4008E-05
.4365E-51	.1409E-02	.4365E-51	.2632E-01	.4365E-51	.2389E-04	.4365E-51	.2047E-03
.4365E-51	.1282E-03	.4365E-51	.8615E-05	.4365E-51	.8335E-04	.4365E-51	.6940E-04
.4365E-51	.3609E-04	.4365E-51	.1039E-04	.4365E-51	.1174E-01	.4365E-51	.2085E-02
.4365E-51	.3133E-01	.4365E-51	.2152E-01	.4365E-51	.1647E-02	.4365E-51	.3821E-02
.4365E-51	.2547E-02	.4365E-51	.1255E-03	.4365E-51	.2785E-03	.4365E-51	.1006E-02
.4851E-51	.6359E-03	.4851E-51	.2314E-04	.4851E-51	.3025E-04	.4851E-51	.4050E-02
.4851E-51	.2314E-04	.4851E-51	.3025E-04	.4851E-51	.9978E-04	.4851E-51	.2314E-04
.4851E-51	.4683E-04	.4851E-51	.3925E-03	.4851E-51	.9815E-03	.4851E-51	.9278E-03
.4851E-51	.2978E-03	.4851E-51	.2602E-03	.4851E-51	.1533E-03	.4851E-51	.7555E-05
.4851E-51	.1699E-03	.4851E-51	.7739E-05	.4851E-51	.1772E-04	.7280E-51	.1092E-03
.7280E-51	.1786E-02	.7280E-51	.1798E-03	.7280E-51	.1366E-03	.7280E-51	.7268E-03
.3597E-38	.1092E-03	.4506E-37	.6080E-04	.4506E-37	.1092E-03	.6135E-37	.1992E-02
.1200E-23	.2561E-02	.1826E-23	.4053E-01	.7354E-23	.1144E-02	.7354E-23	.2561E-02
.1339E-12	.1184E-04	.1339E-12	.3025E-04	.3705E-11	.4008E-05	.3705E-11	.5612E-05
.8333E-10	.2726E-02	.2307E-09	.6359E-03	.3234E-09	.2379E-03	.7393E-09	.1905E-03
.7393E-09	.6359E-03	.8132E-09	.6873E-02	.8534E-09	.1450E-02	.1491E-08	.5697E-02
.2590E-08	.8001E-04	.3062E-08	.1366E-03	.5835E-08	.7268E-03	.7693E-08	.8001E-04
.7693E-08	.4233E-04	.8740E-08	.1328E-02	.8990E-08	.4231E-02	.1083E-07	.1786E-02
.1384E-07	.9278E-03	.2199E-07	.1167E-01	.3119E-07	.3140E-03	.6192E-07	.9278E-03
.6192E-07	.2602E-03	.8970E-07	.1647E-02	.1160E-06	.1992E-02	.1482E-06	.1092E-03
.1553E-06	.3821E-02	.4614E-06	.6080E-04	.4614E-06	.1092E-03	.8300E-06	.1798E-03
.4550E-05	.3925E-02	.5278E-05	.1798E-03	.5278E-05	.1228E-03	.6474E-04	.2695E-02
.9948E-04	.1450E-01	.2231E-03	.3738E-01	.1901E-02	.2726E-02	.4801E-02	.4265E-02
.6281E-02	.2726E-02	.6281E-02	.1328E-02	.6812E-02	.4519E-01	.4617E-01	.5741E-01
.1158E+00	.2271E-01	.1276E+00	.4231E-02	.1816E+01	.5399E+00	.3798E+01	.1992E-02
.3798E+01	.4231E-02						

Table 4-4c. Sorted array for emission radiances (and carried-along weights) for sample Problem 5.

EMISS,WT1 =

0.	0.	.1126E+01	.5612E-05	.1126E+01	.8001E-04	.1126E+01	.3308E-05
.1126E+01	.8001E-04	.1126E+01	.3308E-05	.1126E+01	.1210E-02	.1126E+01	.3308E-05
.1126E+01	.5612E-05	.1126E+01	.1092E-03	.1126E+01	.1992E-02	.1126E+01	.7268E-03
.1126E+01	.1786E-02	.1126E+01	.1092E-03	.1126E+01	.1366E-03	.1126E+01	.1092E-03
.1126E+01	.6080E-04	.1126E+01	.1228E-03	.1126E+01	.1328E-02	.1126E+01	.5612E-05
.1126E+01	.6080E-04	.1126E+01	.2400E-04	.1126E+01	.5446E-04	.1126E+01	.4781E-03
.1126E+01	.4008E-05	.1126E+01	.8001E-04	.1126E+01	.1039E-04	.1126E+01	.8903E-04
.1126E+01	.1962E-05	.1126E+01	.5826E-04	.1126E+01	.4233E-04	.1126E+01	.1255E-03
.1126E+01	.4518E-05	.5296E+01	.7298E-04	.5296E+01	.1132E-03	.5296E+01	.1282E-03
.5296E+01	.5612E-05	.5296E+01	.1053E-04	.5296E+01	.5612E-05	.5296E+01	.1132E-03
.5296E+01	.7298E-04	.5296E+01	.1132E-03	.5296E+01	.1851E-02	.5296E+01	.5612E-05
.5296E+01	.1053E-04	.5296E+01	.1282E-03	.5296E+01	.1798E-03	.5296E+01	.2547E-02
.5296E+01	.2561E-02	.5296E+01	.2152E-01	.5296E+01	.7298E-04	.5296E+01	.2561E-02
.5296E+01	.2561E-02	.5296E+01	.3821E-02	.5296E+01	.1798E-03	.5296E+01	.1798E-03
.5296E+01	.1228E-03	.5296E+01	.1647E-02	.5296E+01	.1144E-02	.5296E+01	.1174E-01
.5296E+01	.3133E-01	.5296E+01	.3925E-02	.5296E+01	.2164E-02	.5296E+01	.4053E-01
.5296E+01	.2573E-02	.5296E+01	.3140E-03	.5296E+01	.2632E-01	.5296E+01	.1228E-03
.5296E+01	.2623E-03	.5296E+01	.1144E-02	.5296E+01	.2156E-02	.5296E+01	.1282E-03
.5296E+01	.1006E-02	.5296E+01	.1851E-02	.5296E+01	.1079E-02	.5296E+01	.1053E-04
.5296E+01	.7760E-02	.5296E+01	.5446E-04	.5296E+01	.1244E-03	.5296E+01	.3865E-03
.5296E+01	.1851E-02	.5296E+01	.8335E-04	.5296E+01	.6940E-04	.5296E+01	.8114E-03
.5296E+01	.4003E-05	.5296E+01	.8615E-05	.5296E+01	.3609E-04	.5296E+01	.2389E-04
.5296E+01	.2047E-03	.5296E+01	.1642E-03	.5296E+01	.1409E-02	.5296E+01	.2785E-03
.5296E+01	.1039E-04	.5296E+01	.2085E-02	.5296E+01	.7143E-04	.5296E+01	.1255E-03
.5296E+01	.8692E-03	.1073E+02	.9278E-03	.1073E+02	.2314E-04	.1073E+02	.2314E-04
.1073E+02	.6359E-03	.1073E+02	.3025E-04	.1073E+02	.2602E-03	.1073E+02	.4050E-02
.1073E+02	.5697E-02	.1073E+02	.2314E-04	.1073E+02	.6359E-03	.1073E+02	.6359E-03
.1073E+02	.1450E-02	.1073E+02	.3925E-03	.1073E+02	.3025E-04	.1073E+02	.9278E-03
.1073E+02	.1905E-03	.1073E+02	.2602E-03	.1073E+02	.9978E-04	.1073E+02	.9278E-03
.1073E+02	.2379E-03	.1073E+02	.2978E-03	.1073E+02	.3025E-04	.1073E+02	.1533E-03
.1073E+02	.6873E-02	.1073E+02	.1699E-03	.1073E+02	.1167E-01	.1073E+02	.1772E-04
.1073E+02	.1184E-04	.1073E+02	.9815E-03	.1073E+02	.4683E-04	.1073E+02	.7739E-05
.1073E+02	.7555E-05	.6389E+02	.1992E-02	.6389E+02	.3821E-02	.6389E+02	.1798E-03
.6389E+02	.1092E-03	.6389E+02	.3738E-01	.6389E+02	.2726E-02	.6389E+02	.1786E-02
.6389E+02	.1450E-01	.6389E+02	.4519E-01	.6389E+02	.3925E-02	.6389E+02	.1092E-03
.6389E+02	.2726E-02	.6389E+02	.6080E-04	.6389E+02	.2695E-02	.6389E+02	.3140E-03
.6389E+02	.1366E-03	.6389E+02	.1798E-03	.6389E+02	.1092E-03	.6389E+02	.1647E-02
.6389E+02	.7268E-03	.6389E+02	.1328E-02	.6389E+02	.1228E-03	.6389E+02	.1798E-03
.6389E+02	.2726E-02	.1208E+03	.4231E-02	.1473E+03	.4265E-02	.1473E+03	.4231E-02
.2227E+03	.5741E-01	.2529E+03	.2271E-01	.2553E+03	.1992E-02	.2553E+03	.4231E-02
.3275E+03	.5435E+00						

Table 4-4d. Cumulative, normalized weight arrays for artificial source transfer-coefficients and emission radiances in sample Problem 5.

WT,WT1 =

0.	0.	.5640E-05	.5620E-05	.8604E-04	.8573E-04	.8936E-04	.8904E-04
.1991E-03	.1691E-03	.2024E-03	.1725E-03	.2635E-03	.1384E-02	.2669E-03	.1387E-02
.2725E-03	.1393E-02	.2966E-03	.1502E-02	.3012E-03	.3497E-02	.7816E-03	.4224E-02
.8364E-03	.6013E-02	.9598E-03	.6122E-02	.9702E-03	.6259E-02	.9722E-03	.6368E-02
.1062E-02	.6429E-02	.1120E-02	.6552E-02	.1246E-02	.7881E-02	.2462E-02	.7887E-02
.2468E-02	.7948E-02	.2581E-02	.7972E-02	.4442E-02	.8026E-02	.4571E-02	.8505E-02
.4581E-02	.8509E-02	.4710E-02	.8589E-02	.4784E-02	.8600E-02	.4897E-02	.8689E-02
.4971E-02	.8691E-02	.6120E-02	.8749E-02	.6194E-02	.8791E-02	.6199E-02	.8917E-02
.6210E-02	.8922E-02	.6216E-02	.8995E-02	.6396E-02	.9108E-02	.6577E-02	.9236E-02
.6691E-02	.9242E-02	.8551E-02	.9253E-02	.1041E-01	.9258E-02	.1080E-01	.9372E-02
.1167E-01	.9445E-02	.1185E-01	.9558E-02	.1198E-01	.1141E-01	.1210E-01	.1142E-01
.1469E-01	.1143E-01	.1500E-01	.1156E-01	.2280E-01	.1174E-01	.2538E-01	.1429E-01
.2619E-01	.1685E-01	.2636E-01	.3839E-01	.2852E-01	.3847E-01	.3247E-01	.4103E-01
.3252E-01	.4359E-01	.3279E-01	.4742E-01	.3387E-01	.4760E-01	.3388E-01	.4778E-01
.3400E-01	.4790E-01	.3618E-01	.4955E-01	.3625E-01	.5070E-01	.3626E-01	.6245E-01
.3767E-01	.9382E-01	.6412E-01	.9776E-01	.6414E-01	.9992E-01	.6435E-01	.1405E+00
.6448E-01	.1431E+00	.6449E-01	.1434E+00	.6457E-01	.1697E+00	.6464E-01	.1699E+00
.6467E-01	.1701E+00	.6469E-01	.1713E+00	.7648E-01	.1734E+00	.7858E-01	.1736E+00
.1101E+00	.1746E+00	.1317E+00	.1764E+00	.1333E+00	.1775E+00	.1372E+00	.1775E+00
.1397E+00	.1853E+00	.1399E+00	.1853E+00	.1401E+00	.1855E+00	.1412E+00	.1859E+00
.1418E+00	.1877E+00	.1419E+00	.1878E+00	.1418E+00	.1879E+00	.1459E+00	.1887E+00
.1459E+00	.1887E+00	.1460E+00	.1887E+00	.1461E+00	.1887E+00	.1461E+00	.1887E+00
.1461E+00	.1890E+00	.1465E+00	.1891E+00	.1475E+00	.1905E+00	.1485E+00	.1908E+00
.1488E+00	.1908E+00	.1490E+00	.1929E+00	.1492E+00	.1930E+00	.1492E+00	.1931E+00
.1493E+00	.1940E+00	.1494E+00	.1949E+00	.1494E+00	.1949E+00	.1495E+00	.1949E+00
.1513E+00	.1956E+00	.1515E+00	.1956E+00	.1516E+00	.1959E+00	.1523E+00	.1999E+00
.1524E+00	.2056E+00	.1525E+00	.2057E+00	.1526E+00	.2063E+00	.1546E+00	.2069E+00
.1572E+00	.2084E+00	.1979E+00	.2088E+00	.1991E+00	.2088E+00	.2016E+00	.2097E+00
.2017E+00	.2099E+00	.2017E+00	.2102E+00	.2017E+00	.2103E+00	.2017E+00	.2112E+00
.2044E+00	.2115E+00	.2051E+00	.2117E+00	.2053E+00	.2118E+00	.2055E+00	.2119E+00
.2061E+00	.2188E+00	.2130E+00	.2190E+00	.2145E+00	.2307E+00	.2202E+00	.2307E+00
.2203E+00	.2307E+00	.2204E+00	.2317E+00	.2212E+00	.2317E+00	.2213E+00	.2317E+00
.2213E+00	.2317E+00	.2226E+00	.2337E+00	.2269E+00	.2376E+00	.2287E+00	.2377E+00
.2296E+00	.2379E+00	.2413E+00	.2753E+00	.2417E+00	.2780E+00	.2426E+00	.2798E+00
.2428E+00	.2943E+00	.2445E+00	.3396E+00	.2465E+00	.3435E+00	.2466E+00	.3436E+00
.2505E+00	.3463E+00	.2505E+00	.3464E+00	.2506E+00	.3491E+00	.2508E+00	.3494E+00
.2548E+00	.3496E+00	.2549E+00	.3497E+00	.2551E+00	.3498E+00	.2578E+00	.3515E+00
.2723E+00	.3522E+00	.3099E+00	.3535E+00	.3126E+00	.3537E+00	.3169E+00	.3539E+00
.3197E+00	.3566E+00	.3210E+00	.3608E+00	.3664E+00	.3651E+00	.4241E+00	.3693E+00
.4469E+00	.4268E+00	.4512E+00	.4495E+00	.9937E+00	.4515E+00	.9957E+00	.4558E+00
.1000E+01	.1000E+01						

STATISTICAL CLOUDS,	P1,P2,P3,P4 =	.10	.25	.50	.90
SOURCE TRANSFER CF	T1,T2,T3,T4 =	.437E-51	.154E-06	.280E+00	.152E+01
EMISSION	E1,E2,E3,E4 =	.530E+01	.639E+02	.261E+03	.314E+03

Table 4-5a. Initial arrays for solar source transfer-coefficients, emission radiances, and weights in sample Problem 5. Wavelength = 2.5 μm.

IDX	LL	MM	HH	TRANS	EMISS	CC=2	CC=3	CC=4	CC=5	WT	WT(SUM)
1	1			.3887E-02	.2553E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.4231E-02
2	2			.2714E-01	.1473E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.8462E-02
3	3			.3171E-01	.1208E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.1269E-01
4	4			.1048E-01	.2227E+03	.1528E-02	.1056E-02	.7331E-02	.4750E-01	.5741E-01	.7011E-01
5	5			.4398E-02	.2529E+03	.8986E-04	.5236E-04	.6506E-03	.2191E-01	.2271E-01	.9281E-01
6	6			.3887E-02	.2553E+03	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.9480E-01
7	7			.2714E-01	.1473E+03	.1498E-04	.8726E-05	0.	.4241E-02	.4265E-02	.9907E-01
8		1		.5061E-01	.6389E+02	.3250E-02	.2120E-02	.1197E-01	.2785E-01	.4519E-01	.1443E+00
9		2		.5061E-01	.6389E+02	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1482E+00
10		3		.5061E-01	.6389E+02	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1502E+00
11			1	.8408E-01	.1126E+01	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1522E+00
12			2	.7621E-01	.5296E+01	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1561E+00
13			3	.7255E-01	.1073E+02	.3325E-02	.1431E-02	.4511E-02	.2403E-02	.1167E-01	.1678E+00
14			4	.7621E-01	.5296E+01	.4388E-02	.2269E-02	.1154E-01	.2234E-01	.4053E-01	.2083E+00
15	1	1		.5061E-01	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2110E+00
16	1	2		.5061E-01	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2112E+00
17	1	3		.5061E-01	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2113E+00
18	2	1		.5061E-01	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2140E+00
19	2	2		.5061E-01	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2142E+00
20	2	3		.5061E-01	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2143E+00
21	3	1		.5061E-01	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2171E+00
22	3	2		.5061E-01	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2172E+00
23	3	3		.5061E-01	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2173E+00
24	4	1		.5061E-01	.6389E+02	.2964E-03	.5480E-03	.6439E-02	.3010E-01	.3738E-01	.2547E+00
25	4	2		.5061E-01	.6389E+02	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2585E+00
26	4	3		.5061E-01	.6389E+02	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2603E+00
27	5	1		.5061E-01	.6389E+02	.1744E-04	.2717E-04	.5715E-03	.1388E-01	.1450E-01	.2748E+00
28	5	2		.5061E-01	.6389E+02	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.2765E+00
29	5	3		.5061E-01	.6389E+02	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.2772E+00
30	6	1		.5061E-01	.6389E+02	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.2785E+00
31	6	2		.5061E-01	.6389E+02	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.2787E+00
32	6	3		.5061E-01	.6389E+02	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.2787E+00
33	7	1		.5061E-01	.6389E+02	.2906E-05	.4529E-05	0.	.2687E-02	.2695E-02	.2814E+00
34	7	2		.5061E-01	.6389E+02	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.2817E+00
35	7	3		.5061E-01	.6389E+02	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.2819E+00
36	1		1	.8408E-01	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2820E+00
37	1		2	.7621E-01	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2822E+00
38	1		3	.7255E-01	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2831E+00
39	1		4	.7621E-01	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2856E+00
40	2		1	.8408E-01	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2858E+00
41	2		2	.7621E-01	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2859E+00
42	2		3	.7255E-01	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2869E+00
43	2		4	.7621E-01	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2894E+00
44	3		1	.8408E-01	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2895E+00
45	3		2	.7621E-01	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2897E+00
46	3		3	.7255E-01	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2906E+00
47	3		4	.7621E-01	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2932E+00
48	4		1	.8408E-01	.1126E+01	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2950E+00
49	4		2	.7621E-01	.5296E+01	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2988E+00
50	4		3	.7255E-01	.1073E+02	.3033E-03	.3699E-03	.2426E-02	.2597E-02	.5697E-02	.3045E+00
51	4		4	.7621E-01	.5296E+01	.4002E-03	.5864E-03	.6206E-02	.2414E-01	.3133E-01	.3358E+00
52	5		1	.8408E-01	.1126E+01	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.3366E+00
53	5		2	.7621E-01	.5296E+01	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.3382E+00
54	5		3	.7255E-01	.1073E+02	.1784E-04	.1834E-04	.2154E-03	.1193E-02	.1450E-02	.3397E+00
55	5		4	.7621E-01	.5296E+01	.2354E-04	.2908E-04	.5508E-03	.1114E-01	.1174E-01	.3514E+00
56	6		1	.8408E-01	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3515E+00
57	6		2	.7621E-01	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3516E+00
58	6		3	.7255E-01	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3518E+00
59	6		4	.7621E-01	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3530E+00

Table 4-5a. (Continued)

60	7		1	.8408E-01	.1126E+01	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.3531E+00
61	7		2	.7621E-01	.5296E+01	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.3534E+00
62	7		3	.7255E-01	.1073E+02	.2973E-05	.3057E-05	0.	.2319E-03	.2379E-03	.3537E+00
63	7		4	.7621E-01	.5296E+01	.3924E-05	.4846E-05	0.	.2155E-02	.2164E-02	.3558E+00
64		1	1	.8408E-01	.1126E+01	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.3572E+00
65		1	2	.7621E-01	.5296E+01	.1453E-04	.4076E-04	.4572E-03	.2060E-02	.2573E-02	.3597E+00
66		1	3	.7255E-01	.1073E+02	.6452E-03	.7428E-03	.3963E-02	.1523E-02	.6873E-02	.3666E+00
67		1	4	.7621E-01	.5296E+01	.8515E-03	.1178E-02	.1014E-01	.1415E-01	.2632E-01	.3929E+00
68		2	1	.8408E-01	.1126E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3931E+00
69		2	2	.7621E-01	.5296E+01	.3348E-06	.1510E-05	.1988E-04	.2405E-03	.2623E-03	.3933E+00
70		2	3	.7255E-01	.1073E+02	.1487E-04	.2751E-04	.1723E-03	.1778E-03	.3925E-03	.3937E+00
71		2	4	.7621E-01	.5296E+01	.1962E-04	.4361E-04	.4407E-03	.1652E-02	.2156E-02	.3959E+00
72		3	1	.8408E-01	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3959E+00
73		3	2	.7621E-01	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3960E+00
74		3	3	.7255E-01	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3963E+00
75		3	4	.7621E-01	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3974E+00
76	1	1	1	.8408E-01	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.3975E+00
77	1	1	2	.7621E-01	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.3977E+00
78	1	1	3	.7255E-01	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.3983E+00
79	1	1	4	.7621E-01	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4001E+00
80	1	2	1	.8408E-01	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4002E+00
81	1	2	2	.7621E-01	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4002E+00
82	1	2	3	.7255E-01	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4002E+00
83	1	2	4	.7621E-01	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4003E+00
84	1	3	1	.8408E-01	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4003E+00
85	1	3	2	.7621E-01	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4003E+00
86	1	3	3	.7255E-01	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4003E+00
87	1	3	4	.7621E-01	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4004E+00
88	2	1	1	.8408E-01	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4005E+00
89	2	1	2	.7621E-01	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4006E+00
90	2	1	3	.7255E-01	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4013E+00
91	2	1	4	.7621E-01	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4031E+00
92	2	2	1	.8408E-01	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4031E+00
93	2	2	2	.7621E-01	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4031E+00
94	2	2	3	.7255E-01	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4032E+00
95	2	2	4	.7621E-01	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4033E+00
96	2	3	1	.8408E-01	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4033E+00
97	2	3	2	.7621E-01	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4033E+00
98	2	3	3	.7255E-01	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4033E+00
99	2	3	4	.7621E-01	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4034E+00
100	3	1	1	.8408E-01	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4035E+00
101	3	1	2	.7621E-01	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4036E+00
102	3	1	3	.7255E-01	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4042E+00
103	3	1	4	.7621E-01	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4061E+00
104	3	2	1	.8408E-01	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4061E+00
105	3	2	2	.7621E-01	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4061E+00
106	3	2	3	.7255E-01	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4061E+00
107	3	2	4	.7621E-01	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4062E+00
108	3	3	1	.8408E-01	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4062E+00
109	3	3	2	.7621E-01	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4062E+00
110	3	3	3	.7255E-01	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4063E+00
111	3	3	4	.7621E-01	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4063E+00
112	4	1	1	.8408E-01	.1126E+01	.1365E-05	.8888E-05	.2033E-03	.9962E-03	.1210E-02	.4075E+00
113	4	1	2	.7621E-01	.5296E+01	.1365E-05	.9999E-05	.2439E-03	.2291E-02	.2547E-02	.4101E+00
114	4	1	3	.7255E-01	.1073E+02	.6062E-04	.1822E-03	.2114E-02	.1694E-02	.4050E-02	.4141E+00
115	4	1	4	.7621E-01	.5296E+01	.8001E-04	.2889E-03	.5406E-02	.1574E-01	.2152E-01	.4357E+00
116	4	2	1	.8408E-01	.1126E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4358E+00
117	4	2	2	.7621E-01	.5296E+01	.3146E-07	.3703E-06	.1060E-04	.2675E-03	.2785E-03	.4361E+00
118	4	2	3	.7255E-01	.1073E+02	.1397E-05	.6748E-05	.9190E-04	.1977E-03	.2978E-03	.4364E+00
119	4	2	4	.7621E-01	.5296E+01	.1843E-05	.1070E-04	.2351E-03	.1838E-02	.2085E-02	.4384E+00

Table 4-5a. (Continued)

120	4	3	1	.8408E-01	.1126E+01	.3146E-07	.2926E-06	.7364E-05	.5057E-04	.5826E-04	.4385E+00
121	4	3	2	.7621E-01	.5296E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4386E+00
122	4	3	3	.7255E-01	.1073E+02	.1397E-05	.5999E-05	.7659E-04	.8597E-04	.1699E-03	.4388E+00
123	4	3	4	.7621E-01	.5296E+01	.1843E-05	.9510E-05	.1959E-03	.7990E-03	.1006E-02	.4398E+00
124	5	1	1	.8408E-01	.1126E+01	.8031E-07	.4407E-06	.1804E-04	.4596E-03	.4781E-03	.4403E+00
125	5	1	2	.7621E-01	.5296E+01	.8031E-07	.4958E-06	.2165E-04	.1057E-02	.1079E-02	.4414E+00
126	5	1	3	.7255E-01	.1073E+02	.3566E-05	.9035E-05	.1876E-03	.7812E-03	.9815E-03	.4423E+00
127	5	1	4	.7621E-01	.5296E+01	.4706E-05	.1432E-04	.4799E-03	.7261E-02	.7760E-02	.4501E+00
128	5	2	1	.8408E-01	.1126E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4502E+00
129	5	2	2	.7621E-01	.5296E+01	.1851E-08	.1836E-07	.9412E-06	.1234E-03	.1244E-03	.4503E+00
130	5	2	3	.7255E-01	.1073E+02	.8216E-07	.3346E-06	.8157E-05	.9121E-04	.9978E-04	.4504E+00
131	5	2	4	.7621E-01	.5296E+01	.1084E-06	.5305E-06	.2086E-04	.8477E-03	.8692E-03	.4512E+00
132	5	3	1	.8408E-01	.1126E+01	.1851E-08	.1451E-07	.6536E-06	.2333E-04	.2400E-04	.4513E+00
133	5	3	2	.7621E-01	.5296E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4513E+00
134	5	3	3	.7255E-01	.1073E+02	.8216E-07	.2975E-06	.6798E-05	.3966E-04	.4683E-04	.4514E+00
135	5	3	4	.7621E-01	.5296E+01	.1084E-06	.4716E-06	.1739E-04	.3686E-03	.3865E-03	.4518E+00
136	6	1	1	.8408E-01	.1126E+01	.6693E-07	.5876E-06	.1203E-04	.2965E-04	.4233E-04	.4518E+00
137	6	1	2	.7621E-01	.5296E+01	.6693E-07	.6611E-06	.1443E-04	.6819E-04	.8335E-04	.4519E+00
138	6	1	3	.7255E-01	.1073E+02	.2972E-05	.1205E-04	.1251E-03	.5040E-04	.1905E-03	.4521E+00
139	6	1	4	.7621E-01	.5296E+01	.3922E-05	.1910E-04	.3199E-03	.4684E-03	.8114E-03	.4529E+00
140	6	2	1	.8408E-01	.1126E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4529E+00
141	6	2	2	.7621E-01	.5296E+01	.1542E-08	.2449E-07	.6275E-06	.7961E-05	.8615E-05	.4529E+00
142	6	2	3	.7255E-01	.1073E+02	.6847E-07	.4462E-06	.5438E-05	.5885E-05	.1184E-04	.4529E+00
143	6	2	4	.7621E-01	.5296E+01	.9037E-07	.7074E-06	.1391E-04	.5469E-04	.6940E-04	.4530E+00
144	6	3	1	.8408E-01	.1126E+01	.1542E-08	.1935E-07	.4358E-06	.1505E-05	.1962E-05	.4530E+00
145	6	3	2	.7621E-01	.5296E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4530E+00
146	6	3	3	.7255E-01	.1073E+02	.6847E-07	.3966E-06	.4532E-05	.2559E-05	.7555E-05	.4530E+00
147	6	3	4	.7621E-01	.5296E+01	.9037E-07	.6288E-06	.1159E-04	.2378E-04	.3609E-04	.4530E+00
148	7	1	1	.8408E-01	.1126E+01	.1339E-07	.7346E-07	0.	.8895E-04	.8903E-04	.4531E+00
149	7	1	2	.7621E-01	.5296E+01	.1339E-07	.8264E-07	0.	.2046E-03	.2047E-03	.4533E+00
150	7	1	3	.7255E-01	.1073E+02	.5943E-06	.1506E-05	0.	.1512E-03	.1533E-03	.4535E+00
151	7	1	4	.7621E-01	.5296E+01	.7844E-06	.2387E-05	0.	.1405E-02	.1409E-02	.4549E+00
152	7	2	1	.8408E-01	.1126E+01	.3084E-09	.2721E-08	0.	.1038E-04	.1039E-04	.4549E+00
153	7	2	2	.7621E-01	.5296E+01	.3084E-09	.3061E-08	0.	.2388E-04	.2389E-04	.4549E+00
154	7	2	3	.7255E-01	.1073E+02	.1369E-07	.5577E-07	0.	.1765E-04	.1772E-04	.4549E+00
155	7	2	4	.7621E-01	.5296E+01	.1807E-07	.8842E-07	0.	.1641E-03	.1642E-03	.4551E+00
156	7	3	1	.8408E-01	.1126E+01	.3084E-09	.2418E-08	0.	.4515E-05	.4518E-05	.4551E+00
157	7	3	2	.7621E-01	.5296E+01	.3084E-09.	.2721E-08	0.	.1038E-04	.1039E-04	.4551E+00
158	7	3	3	.7255E-01	.1073E+02	.1369E-07	.4958E-07	0.	.7676E-05	.7739E-05	.4551E+00
159	7	3	4	.7621E-01	.5296E+01	.1807E-07	.7860E-07	0.	.7134E-04	.7143E-04	.4552E+00
160************				0.	0.	-R	-R	-R	-R	.5435E+00	.9987E+00

IDX = 160 TRANS(160) = .6451E-03 EMISS(160) = .3275E+03 WT (160) = .4385E+00

Table 4-5b. Sorted array for solar source transfer-coefficients (and carried-along weights) for sample Problem 5.

TRANS,WT =

0.	0.	.6451E-03	.4385E+00	.3887E-02	.1992E-02	.3887E-02	.4231E-02
.4398E-02	.2271E-01	.1048E-01	.5741E-01	.2714E-01	.4265E-02	.2714E-01	.4231E-02
.3171E-01	.4231E-02	.5061E-01	.4519E-01	.5061E-01	.3925E-02	.5061E-01	.6080E-04
.5061E-01	.2695E-02	.5061E-01	.3140E-03	.5061E-01	.2726E-02	.5061E-01	.1798E-03
.5061E-01	.1092E-03	.5061E-01	.2726E-02	.5061E-01	.1798E-03	.5061E-01	.1992E-02
.5061E-01	.1228E-03	.5061E-01	.1798E-03	.5061E-01	.1092E-03	.5061E-01	.3738E-01
.5061E-01	.3821E-02	.5061E-01	.1786E-02	.5061E-01	.1450E-01	.5061E-01	.1647E-02
.5061E-01	.7268E-03	.5061E-01	.1328E-02	.5061E-01	.2726E-02	.5061E-01	.1092E-03
.5061E-01	.1366E-03	.7255E-01	.9278E-03	.7255E-01	.1167E-01	.7255E-01	.3025E-04
.7255E-01	.2379E-03	.7255E-01	.9278E-03	.7255E-01	.1450E-02	.7255E-01	.9278E-03
.7255E-01	.6873E-02	.7255E-01	.3025E-04	.7255E-01	.2602E-03	.7255E-01	.2602E-03
.7255E-01	.5697E-02	.7255E-01	.2314E-04	.7255E-01	.6359E-03	.7255E-01	.6359E-03
.7255E-01	.4683E-04	.7255E-01	.3925E-03	.7255E-01	.3025E-04	.7255E-01	.1699E-03
.7255E-01	.2314E-04	.7255E-01	.4050E-02	.7255E-01	.6359E-03	.7255E-01	.9815E-03
.7255E-01	.1184E-04	.7255E-01	.2978E-03	.7255E-01	.1772E-04	.7255E-01	.2314E-04
.7255E-01	.7555E-05	.7255E-01	.7739E-05	.7255E-01	.1905E-03	.7255E-01	.1533E-03
.7255E-01	.9978E-04	.7621E-01	.1798E-03	.7621E-01	.2561E-02	.7621E-01	.2561E-02
.7621E-01	.3821E-02	.7621E-01	.1851E-02	.7621E-01	.3133E-01	.7621E-01	.1228E-03
.7621E-01	.2561E-02	.7621E-01	.1144E-02	.7621E-01	.1798E-03	.7621E-01	.3140E-03
.7621E-01	.2632E-01	.7621E-01	.1647E-02	.7621E-01	.2623E-03	.7621E-01	.1174E-01
.7621E-01	.2156E-02	.7621E-01	.1282E-03	.7621E-01	.2164E-02	.7621E-01	.1851E-02
.7621E-01	.2573E-02	.7621E-01	.1798E-03	.7621E-01	.7298E-04	.7621E-01	.1228E-03
.7621E-01	.1282E-03	.7621E-01	.1144E-02	.7621E-01	.8692E-03	.7621E-01	.3925E-02
.7621E-01	.1132E-03	.7621E-01	.4053E-01	.7621E-01	.5612E-05	.7621E-01	.1282E-03
.7621E-01	.5612E-05	.7621E-01	.1053E-04	.7621E-01	.7298E-04	.7621E-01	.1132E-03
.7621E-01	.7298E-04	.7621E-01	.1132E-03	.7621E-01	.1851E-02	.7621E-01	.5612E-05
.7621E-01	.1053E-04	.7621E-01	.1255E-03	.7621E-01	.2785E-03	.7621E-01	.2547E-02
.7621E-01	.2085E-02	.7621E-01	.2152E-01	.7621E-01	.1409E-02	.7621E-01	.7760E-02
.7621E-01	.1006E-02	.7621E-01	.1244E-03	.7621E-01	.1079E-02	.7621E-01	.6615E-05
.7621E-01	.8335E-04	.7621E-01	.5446E-04	.7621E-01	.8114E-03	.7621E-01	.3865E-03
.7621E-01	.1053E-04	.7621E-01	.3609E-04	.7621E-01	.6940E-04	.7621E-01	.2047E-03
.7621E-01	.4008E-05	.7621E-01	.2389E-04	.7621E-01	.1039E-04	.7621E-01	.1642E-03
.7621E-01	.7143E-04	.8408E-01	.1092E-03	.8408E-01	.6080E-04	.8408E-01	.7268E-03
.8408E-01	.1786E-02	.8408E-01	.1092E-03	.8408E-01	.1366E-03	.8408E-01	.6001E-04
.8408E-01	.6080E-04	.8408E-01	.1228E-03	.8408E-01	.1328E-02	.8408E-01	.1092E-03
.8408E-01	.3308E-05	.8408E-01	.5612E-05	.8408E-01	.8001E-04	.8408E-01	.3308E-05
.8408E-01	.8001E-04	.8408E-01	.1255E-03	.8408E-01	.1210E-02	.8408E-01	.3308E-05
.8408E-01	.5612E-05	.8408E-01	.5826E-04	.8408E-01	.4233E-04	.8408E-01	.2400E-04
.8408E-01	.5446E-04	.8408E-01	.4781E-03	.8408E-01	.4008E-05	.8408E-01	.4518E-05
.8408E-01	.1039E-04	.8408E-01	.8903E-04	.8408E-01	.1962E-05	.8408E-01	.5612E-05
.8408E-01	.1992E-02						

Table 4-5c. Cumulative, normalized weight arrays for solar source transfer-coefficients and emission radiances in sample Problem 5.

WT,WT1 =

0.	0.	.4907E+00	.5620E-05	.4929E+00	.8573E-04	.4976E+00	.8904E-04
.5231E+00	.1691E-03	.5873E+00	.1725E-03	.5921E+00	.1384E-02	.5968E+00	.1387E-02
.6015E+00	.1393E-02	.6521E+00	.1502E-02	.6565E+00	.3497E-02	.6566E+00	.4224E-02
.6596E+00	.6013E-02	.6599E+00	.6122E-02	.6630E+00	.6259E-02	.6632E+00	.6368E-02
.6633E+00	.6429E-02	.6663E+00	.6552E-02	.6666E+00	.7881E-02	.6688E+00	.7887E-02
.6689E+00	.7948E-02	.6691E+00	.7972E-02	.6692E+00	.8026E-02	.7111E+00	.8505E-02
.7153E+00	.8509E-02	.7173E+00	.8589E-02	.7336E+00	.8600E-02	.7354E+00	.8689E-02
.7362E+00	.8691E-02	.7377E+00	.8749E-02	.7408E+00	.8791E-02	.7409E+00	.8917E-02
.7410E+00	.8922E-02	.7421E+00	.8995E-02	.7551E+00	.9108E-02	.7552E+00	.9236E-02
.7554E+00	.9242E-02	.7565E+00	.9253E-02	.7581E+00	.9258E-02	.7591E+00	.9372E-02
.7668E+00	.9445E-02	.7669E+00	.9558E-02	.7671E+00	.1141E-01	.7674E+00	.1142E-01
.7738E+00	.1143E-01	.7738E+00	.1156E-01	.7745E+00	.1174E-01	.7753E+00	.1429E-01
.7753E+00	.1685E-01	.7757E+00	.3839E-01	.7758E+00	.3847E-01	.7760E+00	.4103E-01
.7760E+00	.4359E-01	.7805E+00	.4742E-01	.7812E+00	.4760E-01	.7823E+00	.4778E-01
.7824E+00	.4790E-01	.7827E+00	.4955E-01	.7827E+00	.5070E-01	.7827E+00	.6245E-01
.7827E+00	.9382E-01	.7827E+00	.9776E-01	.7830E+00	.9992E-01	.7831E+00	.1405E+00
.7832E+00	.1431E+00	.7834E+00	.1434E+00	.7863E+00	.1697E+00	.7892E+00	.1699E+00
.7935E+00	.1701E+00	.7955E+00	.1713E+00	.8306E+00	.1734E+00	.8307E+00	.1736E+00
.8336E+00	.1746E+00	.8349E+00	.1764E+00	.8351E+00	.1775E+00	.8354E+00	.1775E+00
.8649E+00	.1853E+00	.8667E+00	.1853E+00	.8670E+00	.1855E+00	.8801E+00	.1859E+00
.8825E+00	.1877E+00	.8827E+00	.1878E+00	.8851E+00	.1879E+00	.8872E+00	.1887E+00
.8901E+00	.1887E+00	.8903E+00	.1887E+00	.8903E+00	.1887E+00	.8905E+00	.1887E+00
.8906E+00	.1890E+00	.8919E+00	.1891E+00	.8929E+00	.1905E+00	.8973E+00	.1908E+00
.8974E+00	.1908E+00	.9427E+00	.1929E+00	.9428E+00	.1930E+00	.9429E+00	.1931E+00
.9429E+00	.1940E+00	.9429E+00	.1949E+00	.9430E+00	.1949E+00	.9431E+00	.1949E+00
.9432E+00	.1956E+00	.9433E+00	.1956E+00	.9454E+00	.1959E+00	.9454E+00	.1999E+00
.9454E+00	.2056E+00	.9456E+00	.2057E+00	.9459E+00	.2063E+00	.9487E+00	.2069E+00
.9511E+00	.2084E+00	.9751E+00	.2088E+00	.9767E+00	.2088E+00	.9854E+00	.2097E+00
.9865E+00	.2099E+00	.9867E+00	.2102E+00	.9879E+00	.2103E+00	.9879E+00	.2112E+00
.9880E+00	.2115E+00	.9880E+00	.2117E+00	.9889E+00	.2118E+00	.9894E+00	.2119E+00
.9894E+00	.2188E+00	.9894E+00	.2190E+00	.9895E+00	.2307E+00	.9897E+00	.2307E+00
.9897E+00	.2307E+00	.9898E+00	.2317E+00	.9898E+00	.2317E+00	.9900E+00	.2317E+00
.9900E+00	.2317E+00	.9902E+00	.2337E+00	.9902E+00	.2376E+00	.9910E+00	.2377E+00
.9930E+00	.2379E+00	.9932E+00	.2753E+00	.9933E+00	.2780E+00	.9934E+00	.2798E+00
.9935E+00	.2943E+00	.9936E+00	.3396E+00	.9951E+00	.3435E+00	.9952E+00	.3436E+00
.9952E+00	.3463E+00	.9952E+00	.3464E+00	.9953E+00	.3491E+00	.9953E+00	.3494E+00
.9954E+00	.3496E+00	.9955E+00	.3497E+00	.9969E+00	.3498E+00	.9969E+00	.3515E+00
.9969E+00	.3522E+00	.9970E+00	.3535E+00	.9970E+00	.3537E+00	.9970E+00	.3539E+00
.9971E+00	.3566E+00	.9976E+00	.3608E+00	.9976E+00	.3651E+00	.9977E+00	.3693E+00
.9977E+00	.4268E+00	.9978E+00	.4495E+00	.9978E+00	.4515E+00	.9978E+00	.4558E+00
.1000E+01	.1000E+01						

STATISTICAL CLOUDS,	P1,P2,P3,P4 =	.10	.25	.50	.90
SUN TRANSFER COEF	S1,S2,S3,S4 =	.131E-03	.329E-03	.393E-02	.762E-01
EMISSION	E1,E2,E3,E4 =	.530E+01	.639E+02	.261E+03	.314E+03

Table 4-6. Definitions of quantities in Tables 4-4a and 4-5a.

Column	Heading	Description
1	IDX	Cloud-configuration index
2,3,4	LL,MM,HH	Cloud indexes for low-, medium-, and high-layer clouds
5	TRANS	Transfer coefficient (for artificial source in Table 4-4a and for solar source in Table 4-5a)
6	EMISS	Emission radiance from highest cloud in set (independent of type of source)
7,8,9,10	CC=2,3,4,5	Weights or relative occurrence frequencies of given cloud set with cloud-coverage category CC (or cloud-coverage fractions of 0.3, 0.5, 0.8, and 1.0)
11	WT	Total weight or relative occurrence frequency of given cloud set (sum of weights for CC=2,3,4,5)
12	WT(SUM)	Cumulative sum of WT for all cloud-configuration sets

(Appendix Equation (30a)) exceeds 100. In this event function TRANSF uses the initialized value of FLUX, 1.E-50, an arbitrarily small value. The results for IDX=160 are provided by subroutine SCLOUD for the Earth's surface. The initial setting of WT(160), the probability of seeing the ground with or without clouds being present, occurs in subroutine CLDWT, and the corresponding WT(SUM) would be exactly 1.0 except for small numerical inconsistencies. WT(160) is reset in subroutine SCLOUD to take account of the two-leg CFLOS required to see tha ground lighted by the source (either artificial or the sun).

Before sorting the TRANS and EMISS arrays, we have augmented each of them (as well as the WT and WT1 arrays) with one additional member whose value is set to zero. This procedure allows subroutine LINEAR to interpolate within the array given to it when the weight of the smallest (nonzero) member exceeds the smallest fractile (now 0.10) for which an integral-distribution value is desired.

Tables 4-4b and 4-5b give the TRANS array after it has been sorted (by a call to subroutine SORTLJ from subroutine SCLOUD) in the order of increasing values. The WT array is simply carried along. The TRANS and WT values are presented in pairs in Tables 4-4b and 4-5b.

Table 4-4c gives the EMISS array after it has been sorted in the order of increasing values. The WT1 array is simply carried along. The EMISS and WT1 values are presented in pairs in Table 4-c.

Tables 4-4d and 4-5c give the cumulative, normalized weight arrays WT and WT1; these quantities are also presented in pairs.

At the end of Tables 4-4d and 4-5c the values of the transfer coefficient and emission radiance are given corresponding to the four user-selected fractiles (here taken to be 0.10, 0.25, 0.50, and 0.90) determined from the cumulative, normalized weight arrays WT (for transfer coefficient) and WT1 (for emission radiance).

We repeat, as noted in Section 2.2, that in the 160-member distributions for the solar source transfer-coefficients and emission radiances, there are only 10 different values (nine for clouds, one for the Earth) because (a) there are only nine different cloud-top altitudes (cf. Table 2-1), (b) the bidirectional reflectance of any cloud is assumed to be approximated by that for cloud-type 4 (stratocumulous), and (c) the directional emissivity computed for cloud-type 4 is used for all cloud types. We have collated the essential results for the solar source transfer-coefficient array in Table 4-7a and those for the emission radiance

Table 4-7a. Solar source transfer-coefficient distribution for sample Problem 5.

IDX	TCOEF sr^{-1}	No. Of Cases	Total Weight	Cumul. Weight	Fractiles	TCOEF sr^{-1}	CLDTOP km	TAIR	$(TAIR)^2$
					0.10	0.131^{-3}			
					0.25	0.329^{-3}			
160	0.6451^{-3}	1	0.4907	0.4907			0.0	0.1424	0.02027
1,6	0.3887^{-2}	2	0.0069	0.4976			1.0	0.2150	0.04622
					0.50	0.393^{-2}			
5	0.4398^{-2}	1	0.0255	0.5231			1.15	0.2287	0.05231
4	0.1048^{-1}	1	0.0642	0.5873			2.3	0.3531	0.1247
2,7	0.2714^{-1}	2	0.0095	0.5968			4.0	0.5681	0.3227
3	0.3171^{-1}	1	0.0047	0.6015			4.5	0.6141	0.3771
8,9,10	0.5061^{-1}	24	0.1395	0.7410			6.0	0.7758	0.6019
13	0.7255^{-1}	32	0.0422	0.7832			9.0	0.9289	0.8628
12,14	0.7621^{-1}	64	0.2068	0.9900	0.90	0.762^{-1}	10.0	0.9520	0.9063
11	0.8408^{-1}	32	0.0100	1.0000			12.0	1.0	1.0
		160	1.0000						

array in Table 4-7b. These latter two tables should facilitate understanding the values of the solar transfer-coefficient and emission radiance for the fractiles 0.10, 0.25, 0.50, and 0.90 printed at the end of Table 4-5c.

The variation in values of the (attenuated) solar source transfer-coefficient (TCOEF) for the nine cloud tops is due only to the variation in the (two-leg) air transmittance between the different cloud-top altitudes and 12-km altitude, as verified by our including in Table 4-7a the cloud-top altitude and the air transmittance from the cloud-top altitude to 12-km altitude. The variation in values of the (attenuated) emission radiance (EMISS) for the nine cloud tops is due to the combined effects of (a) the (one-leg) air transmittances from the different cloud-top altitudes to 12-km altitude and (b) the temperature entering the Planck emission function.

In the distributions presented in Tables 4-7a and 4-7b the importance of the Earth's surface is apparent since it has by far the largest single weight associated with it. This feature occurs not only for the data in KMODEL=1 but for the data given in BLOCK DATA for each of the 10 KMODELs. To illustrate this general feature we have evaluated the probability (P_{gnd}) for a detector, pointed straight down, of seeing the ground either with or without clouds being present:

$$
\begin{aligned}
P_{gnd} = {} & \mathrm{CCOVER}(1,K) + \\
& \mathrm{CCOVER}(2,K) \times \mathrm{CFLOSF}(4,\theta) + \\
& \mathrm{CCOVER}(3,K) \times \mathrm{CFLOSF}(6,\theta) + \\
& \mathrm{CCOVER}(4,K) \times \mathrm{CFLOSF}(9,\theta) + \\
& \mathrm{CCOVER}(5,K) \times \mathrm{CLFOSF}(11,\theta)
\end{aligned}
$$

where K = KMODEL and θ = 0 degrees.

The results are:

KMODEL	P_{gnd}	KMODEL	P_{gnd}
1	0.543	6	0.611
2	0.543	7	0.666
3	0.484	8	0.591
4	0.633	9	0.628
5	0.513	10	0.559

Table 4-7b. Emission radiance distribution function for sample Problem 5.

IDX	EMISS $\frac{W}{km^2\ sr\ \mu m}$	No. of Cases	Total Weight	Cumul. Weight	Fractiles	EMISS $\frac{W}{km^2\ sr\ \mu m}$	CLDTOP km	T °K	ε × PLANCK $\frac{W}{km^2\ sr\ \mu m}$	TAIR	ε × PLANCK × TAIR $\frac{W}{km^2\ sr\ \mu m}$
11	1.1	32	0.0089	0.8922^{-2}			12.0	210.00	1.13	1.0	1.1
12,14	5.3	64	0.1851	0.1940	0.10	5.3	10.0	223.00	5.56	0.9520	5.3
13	10.7	32	0.0377	0.2317			9.0	229.50	11.55	0.9289	10.7
8,9,10	63.9	24	0.1249	0.3566	0.25	63.9	6.0	249.00	82.35	0.7758	63.9
3	120.8	1	0.0042	0.3608			4.5	258.75	196.74	0.6141	120.8
2,7	147.3	2	0.0085	0.3693			4.0	262.00	259.25	0.5681	147.3
4	222.7	1	0.0575	0.4268			2.3	273.05	630.64	0.3531	222.7
5	252.9	1	0.0227	0.4495			1.15	280.52	1105.88	0.2287	252.9
1,6	255.3	2	0.0063	0.4558			1.0	281.50	1187.30	0.2150	255.3
					0.50	261					
					0.90	314					
160	327.5	1 160	0.5442 1.0000	1.0000			0.0	288.00	2300.40	0.1424	327.5

It is instructive to relate some of the Problem-5 results to those for Problems 1 to 3. The cloud configurations for IDX equal to 4, 8, and 13 in Table 4-4a are the same as those for Problems 1, 2, and 3, respectively. Since the source is below all clouds in both cases, we should expect the (transmission) transfer coefficients in Table 4-4a to correspond to those at zero lateral displacement in Problems 1, 2, and 3, except that air attenuation is included in Problem 5 but not in Problems 1, 2, and 3. However, the air-attenuation path is the same (cf. Figure 2-6b) for all cloud configurations in Problem 5. Thus, we expect that the TRANS results given in Table 4-4a for IDX = 4, 8, and 13 will differ by a constant factor from those for zero lateral displacement in Problems 1 to 3. To predict this factor we write:

$$\mathrm{TRANS(Pm\ 5)} = \mathrm{TC'(Pms\ 1,2,3)} \times \mathrm{TAIR(2.5,0.,0.01)} \times (\mathrm{SDISTO})^2 .$$

By using the interpolation-extrapolation scheme for air transmittance as described in Section 3-2.28, we hand-calculate the air transmittance to be

$$\mathrm{TAIR} = T_1\ (T_1/T_2)^{-(h-h_1)/(h_2-h_1)}$$

$$= (0.2150)\ (0.2150/0.3247)^{-(0.01-1)/(2-1)}$$

$$= 0.1430$$

and

$$(\mathrm{SDISTO})^2 = (11.99)^2 \quad .$$

Thus we predict

$$\mathrm{TRANS} = 20.55\ \mathrm{TC'} \quad .$$

It is satisfying that our prediction is correct, as seen from the data in Table 4-8.

The reason we did not include IDX=114 and Problem 4 in this comparison is that the integral to be evaluated for TRANS in Table 4-4a was skipped owing to the large argument of the sinh and cosh functions and the concomitant smallness of the value of TRANS. (See the related comment made previously with respect to Table 4-4a.)

Table 4-8. Comparison of transfer coefficients from Problem 5 with modified transfer coefficients from Problems 1 to 3.

IDX	TRANS[a] sr^{-1}	$(TC')^b$ $sr^{-1}\ km^{-2}$	TRANS/TC' km^2
4	0.4617^{-1}	0.2247^{-2}	20.55
8	0.6812^{-2}	0.3315^{-3}	20.55
13	0.2199^{-7}	0.1070^{-8}	20.55

[a]From Table 4-4a.
[b]From Table 4-2 for RANGE=0.0.

4-3.3 Problem 6: Use of the deterministic cloud submodel for an ellipsoidal cloud

Problem 6 illustrates the selection by subroutine LOS of lines-of-sight and the evaluation by subroutine CLOUD3 of transfer coefficients and emission radiances for these same lines-of-sight.

For this problem we have placed a single ellipsoidal cloud at 10-km altitude. The lengths of the semiaxes are a=4 km, b=2 km, and c=1 km. The cloud's properties are those for the Type-4 cloud (stratocumulous; see Table 2-1). The artificial source is also placed at 10-km altitude and 10 km to the east of the cloud center. The solar source has a zenith angle of 45 degrees. The detector is at synchronous altitude, directly above the cloud. Wavelength is 2.5 μm. We have made two runs, one (Problem 6a) with FOV = 1 km^2 and the other (Problem 6b) with FOV = 20 km^2. The input deck is shown in Figure 4-5.

Figure 4-6a is an outline of the cloud in a horizontal plane through its center. The 64 different x,y coordinates of the facet centers are shown by small dots. The 16 x,y coordinates of the facet centers that are considered in subroutine LOS by incrementing the facet-center indexes by two's are denoted by crosses.

Figure 4-6b pertains to the cloud for the artificial source. We show the 16 above-defined facet centers visible to the detector, marked by crosses. Of these, the three that are also visible to the source are marked as RI(R denotes reflective, I the sequence number (1 to 3)). For FOV = 1 km^2, each of these three reflective points

```
******************* PROBLEM 6A ************************************
   HD        THETAD     PHID      FOV                DETECTOR
 35793.     90.00001   -90.0001   1.0
HSORCE(1) THETAS(1)  PHIS(1)     WKT                SOURCE
 10.        90.000001   -89.90    1000.
      ISUN
         1
  ALAM
  2.50
      MODE                                           DETERMINISTIC        CARD 1
         0
    NCLOUD                                           NO. OF CLOUDS        CARD 2
         1
KCLOUD                                               CLOUD PROPERTIES     CARD 3
    HCLOUD THETCD    PHICD    CLOUDA    CLOUDB    CLOUDC    CLDPSI
 4   10.     90.      -90.       4.0       2.0       1.0       0.

******************* PROBLEM 6B ************************************
   HD        THETAD     PHID      FOV                DETECTOR
 35793.     90.00001   -90.0001   20.
HSORCE(1) THETAS(1)  PHIS(1)     WKT                SOURCE
 10.        90.000001   -89.90    1000.
      ISUN
         1
  ALAM                                               WAVELENGTH
  2.50
      MODE                                           DETERMINISTIC        CARD 1
         0
    NCLOUD                                           NO. OF CLOUDS        CARD 2
         1
KCLOUD                                               CLOUD PROPERTIES     CARD 3
    HCLOUD THETCD    PHICD    CLOUDA    CLOUDB    CLOUDC    CLDPSI
 4   10.     90.      -90.       4.0       2.0       1.0       0.
```

Figure 4-5. Input data for Problems 6a and 6b.

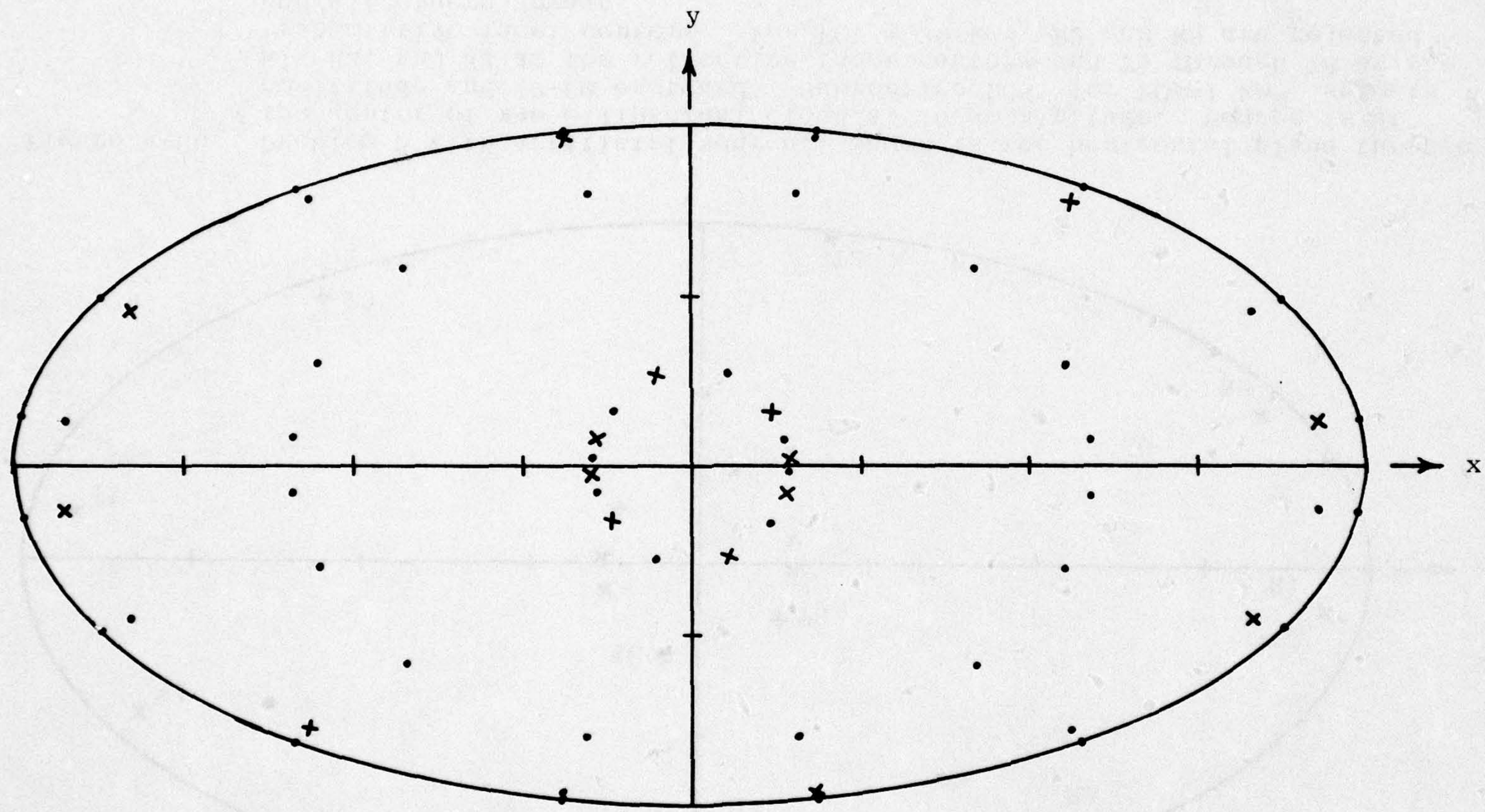

Figure 4-6a. Problem 6 cloud. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Projected positions of all facet centers are indicated by dots; those examined in subroutine LOS for visibility are marked with crosses.

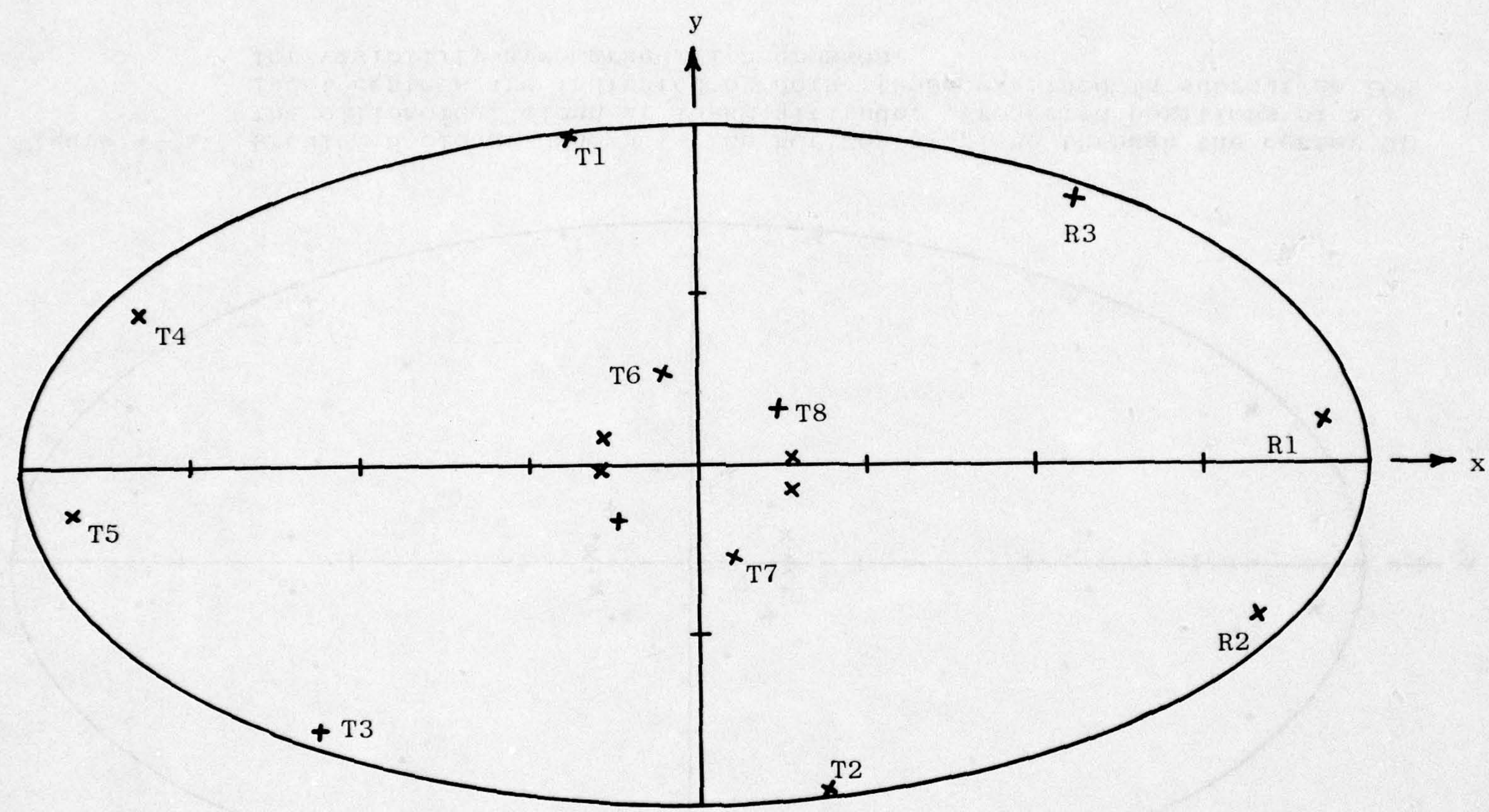

Figure 4-6b. Problem 6 with artificial source. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Source is at coaltitude and 10-km eastward. Subroutine LOS, for FOV=1 km^2, selects R1, R2, and R3 as the reflective facet centers and T1 through T8 as the transmittive facet centers. For FOV = 20 km^2, R2 and R3 are rejected and all others remain.

survives the selection process since none lines within 0.7 $\sqrt{FOV}$ of another. For FOV = 20 km^2, R2 and R3 do not survive the selection process. The remaining 13 points (16 minus 3) are transmittive; of these, eight (the maximum number of transmittive points retained by the code) are marked as TI (T denotes transmittive, I the sequence number (1 to 8). These same eight points obtain for both values of FOV.

Figures 4-6c and 4-6d pertain to the cloud for the solar source and correspond to FOV being 1 km^2 and 20 km^2, respectively. Again we show the 16 facet centers visible to the detector, marked by crosses. All of these facet centers are visible to the sun; there are no transmittive points. For FOV = 1 km^2, 11 of the points (marked as R1 through R11 in Figure 4-6c) survive the selection process; for FOV = 20 km^2, four of the points (marked as R1 through R4 in Figure 4-6d) survive the selection process.

The transfer coefficients, emission radiances, and cloud coordinates of the facet centers for both sources and FOV's are given in Table 4-9, to which a guide is provided in Table 10. The coordinates of the first reflective point and the eight transmittive points are, of course, the same in Parts (a) and (b).

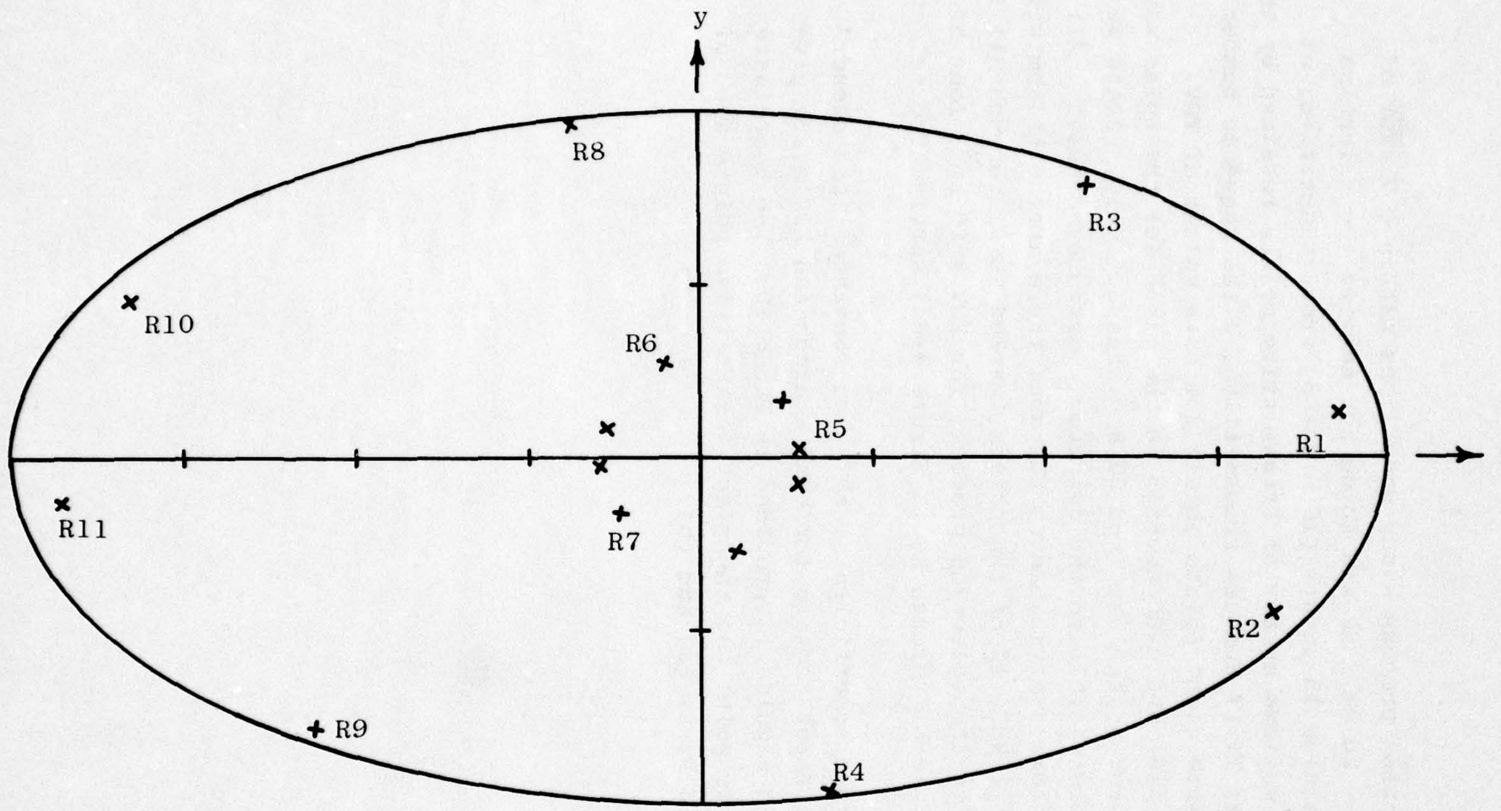

Figure 4-6c. Problem 6a with solar source. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Source is the sun, eastward at 45-deg zenith angle. Subroutine LOS, for FOV=1 km^2, selects R1 through R11 as the reflective facet centers. There are no transmittive facet centers.

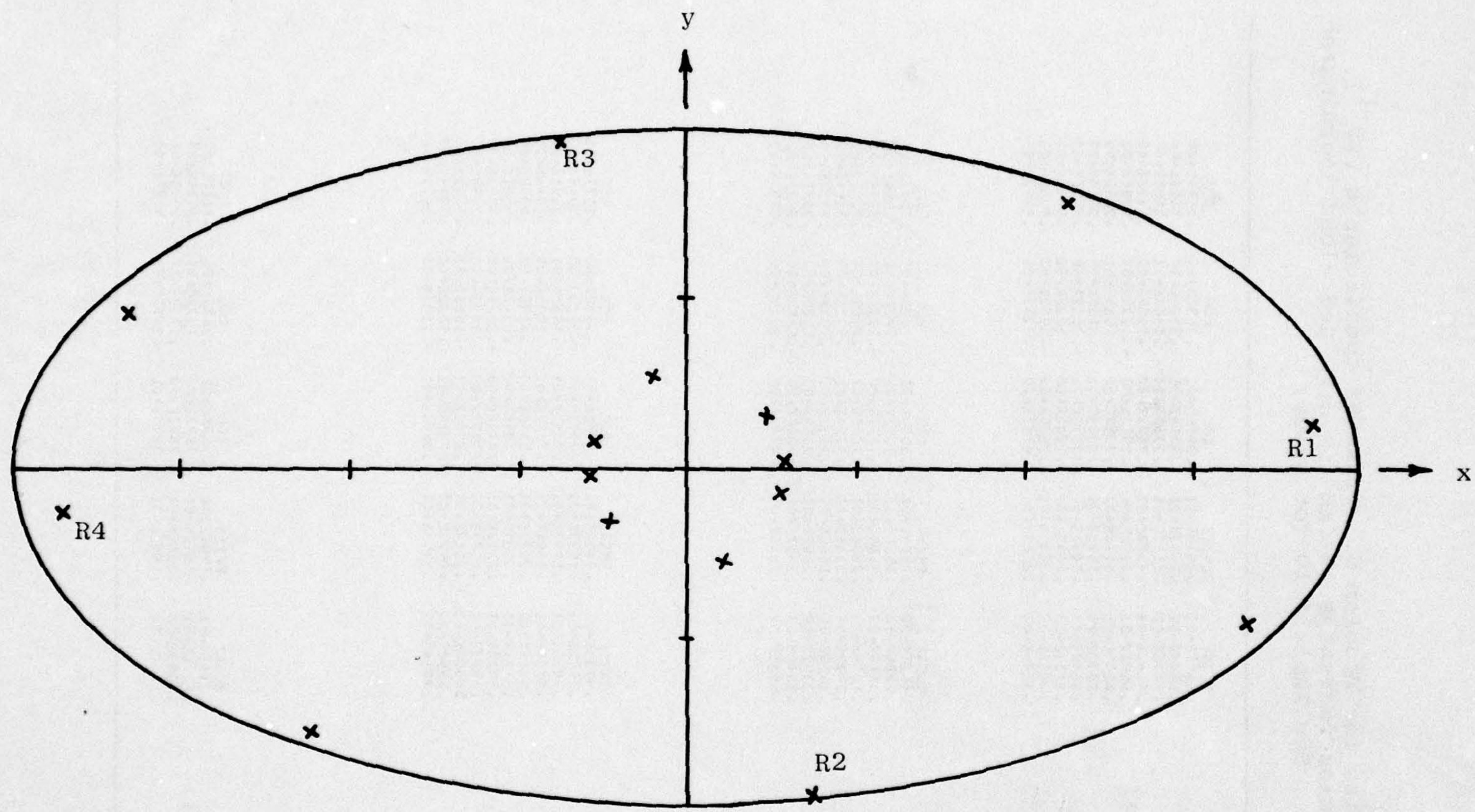

Figure 4-6d. Problem 6b with solar source. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Source is the sun, eastward at 45-deg zenith angle. Subroutine LOS, for FOV=20 km^2, selects R1 through R4 as the reflective facet centers. There are no transmittive facet centers.

Table 4-9. Results for Problem 6. Transfer coefficients (sr^{-1}), emission radiances ($W/(km^2\ sr\ \mu m)$), and cloud coordinates (km). See Table 4-10 for guide.

(a)

TCOEF	EMISS	XCC	YCC	ZCC
.3483E-01	.2492E+01	.3698E+01	.2633E+00	.3577E+00
.1844E-01	.1573E+01	.3314E+01	-.9026E+00	.3314E+00
.5076E-02	.1117E+01	.2260E+01	.1563E+01	.2651E+00
.4383E-04	.4348E+01	-.7572E+00	.1923E+01	.1994E+00
.6605E-03	.4352E+01	.7572E+00	-.1923E+01	.1994E+00
.5299E-06	.1118E+01	-.2260E+01	-.1563E+01	.2651E+00
.1079E-06	.1573E+01	-.3314E+01	.9026E+00	.3314E+00
.8940E-07	.2493E+01	-.3698E+01	-.2633E+00	.3577E+00
.1151E-03	.2635E+01	-.2080E+00	.5282E+00	.9631E+00
.2615E-03	.2635E+01	.2080E+00	-.5282E+00	.9631E+00
.3276E-03	.2603E+01	.4747E+00	.3283E+00	.9793E+00

(b)

TCOEF	EMISS	XCC	YCC	ZCC
.4626E-02	.1501E+01	.3698E+01	.2633E+00	.3577E+00
.7286E-03	.3561E+01	-.7572E+00	.1923E+01	.1994E+00
.3771E-02	.3565E+01	.7572E+00	-.1923E+01	.1994E+00
.1054E-03	.3086E+01	-.2260E+01	-.1563E+01	.2651E+00
.1722E-04	.2300E+01	-.3314E+01	.9026E+00	.3314E+00
.1650E-05	.1502E+01	-.3698E+01	-.2633E+00	.3577E+00
.2307E-02	.2552E+01	-.2080E+00	.5282E+00	.9631E+00
.3846E-02	.2552E+01	.2080E+00	-.5282E+00	.9631E+00
.5055E-02	.2515E+01	.4747E+00	.3283E+00	.9793E+00

(c)

TCOEF	EMISS	XCC	YCC	ZCC
.4833E-01	.2492E+01	.3698E+01	.2633E+00	.3577E+00
.2992E-01	.1573E+01	.3314E+01	-.9026E+00	.3314E+00
.1930E-01	.1117E+01	.2260E+01	.1563E+01	.2651E+00
.5125E-01	.4352E+01	.7572E+00	-.1923E+01	.1994E+00
.6405E-01	.2581E+01	.5816E+00	.4140E-01	.9892E+00
.5751E-01	.2635E+01	-.2080E+00	.5282E+00	.9631E+00
.5927E-01	.2603E+01	-.4747E+00	-.3283E+00	.9793E+00
.4914E-01	.4348E+01	-.7572E+00	.1923E+01	.1994E+00
.5535E-02	.1118E+01	-.2260E+01	-.1563E+01	.2651E+00
.6696E-02	.1573E+01	-.3314E+01	.9026E+00	.3314E+00
.8916E-02	.2493E+01	-.3698E+01	-.2633E+00	.3577E+00

(d)

TCOEF	EMISS	XCC	YCC	ZCC
.2768E-01	.1501E+01	.3698E+01	.2633E+00	.3577E+00
.4876E-01	.3565E+01	.7572E+00	-.1923E+01	.1994E+00
.4263E-01	.3561E+01	-.7572E+00	.1923E+01	.1994E+00
.1612E-01	.1502E+01	-.3698E+01	-.2633E+00	.3577E+00

Table 4-10. Guide to Table 4-9 results.

Table 4-9 Part	Source	FOV km^2	Reflective Points	Transmittive Points
(a)	Artificial	1	3	8
(b)	Artificial	20	1	8
(c)	Solar	1	11	0
(d)	Solar	20	4	0

SECTION 5
REFERENCES

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APPENDIX A
SOME DIFFUSION PROBLEM SOLUTIONS

A-1 INTRODUCTION

The problem of determining the light flux out of clouds in various configurations of clouds and sources recurs frequently. For convenience the results for a number of such problems are collected here. No claim is made that these are novel or original, many of the solutions being well-known or using standard methods. A unified compilation with a consistent terminology may nevertheless be useful.

A rigorous treatment using the transport equation or Monte Carlo methods to evaluate the effects of scattering and absorption would be, at best, extremely time consuming. Additionally, the specification of the geometry of the clouds only approximates real cloud configurations, making such a careful evaluation of flux overly elaborate. Therefore the approach taken here has been to solve the problem in the approximation of the diffusion equation. The basic assumptions are that there be many scatterings and that precise surface effects be unimportant. An improvement over the most elementary diffusion equation solutions can be achieved by using scattering parameters based on rigorous transport theory or by using the results of Monte Carlo calculations to adjust the results.

A-1.1 Basic Equations

The development follows the lines indicated by Weinberg and Wigner[1] for neutrons. The basic equation to be solved is the diffusion equation:

$$D \text{ div grad } \phi - \Sigma_a \phi + S = \frac{1}{v} \frac{\partial \phi}{\partial t} \tag{1}$$

where: ϕ is the light flux, photons/(cm^2 sec)

D is the diffusion coefficient

Σ_a is the macroscopic absorption cross-section

S is the light source per unit volume per unit time, photons/(cm^3 sec)

v is the speed of light

The required boundary conditions are given in terms of the flux:

$$J_{\pm} = a\phi + b\left(\mp \frac{\partial\phi}{\partial Z} - \frac{3}{2v}\frac{\partial\phi}{\partial t}\right) \quad (2)$$

$J_{\pm}$ is the flux in the $\pm$ Z direction.

The constants, a and b, are left arbitrary. From the usual definition of flux, $b = D/2$. In "standard" usage, $a = \Sigma_s/4\Sigma$, $D = \Sigma_s/3\Sigma\Sigma_{tr}$, and $\Sigma_{tr} = \Sigma - \bar{\mu}\Sigma_s$ where Σ, Σ_s, and Σ_{tr} are the macroscopic total, scattering, and transport cross-sections, respectively, and $\bar{\mu}$ is the average cosine of the scattering angle. Here a and b are left undermined to allow later evaluation using better values based on suitable exact calculations. In general the physical boundary conditions require a specified inward flux, sometimes zero. The frequently used "extrapolated end-point" formulation relates ϕ and $\partial\phi/\partial Z$ on the surface. The desired quantities are the emerging fluxes, the actual flux distribution inside the medium being of, at most, peripheral interest.

A-1.2 Diffusion Parameters for an Absorbing medium

In Section A-1.1 the "standard" evaluation was given for the diffusion parameters in terms of the macroscopic cross-sections. That evaluation is strictly applicable only in the limit of small absorption. A more generally applicable evaluation, which we adopt for numerical results in this report, is described in this section.

Case, de Hoffmann, and Placzek[2] provide material suitable for a better evaluation based on exact solutions of some problems. The results of Case et al.[2] are derived for isotropic scattering. In the present application, some modification has been made to account, at least partially, for anisotropic scattering. A judicious utilization of the transport cross-section (which introduces the anisotropy) must be made.

Case et al.[2] use several parameters to which we must refer:

c = average number of emergent particles per collision (cf. Reference 2, p. 43)

$$= \Sigma_s/\Sigma \quad (3)$$

$$= \begin{cases} 0 \text{ for pure absorption} \\ 1 \text{ for pure scattering} \end{cases}$$

$1/\kappa_o(c)$ = diffusion length (dimensionless) (cf. Reference 2, p. 55)

$\lambda(c)$ = linear extrapolation length (dimensionless) (cf. Reference 2, p. 137)

The parameter $\kappa_o(c)$, determined by c according to Equation (68) on p. 55 of Reference 2,

$$c = \kappa_o/\tanh^{-1}\kappa_o \quad , \tag{4}$$

is tabulated and plotted in Reference 2 (pp. 60, 63; Figure 16 on p. 56). The parameter $\lambda(c)$ is also tabulated and plotted in Reference 2 (p. 136; Figure 35 on p. 138). Tabular values of $\kappa_o(c)$ and $\lambda(c)$ are given here in Table A-1. (In the computer code, we use more closely-spaced values of κ_o.)

Since $\kappa_o(c)$ and $\lambda(c)$ are dimensionless, we are free to associate scale lengths with them in some reasonable way. We do so by choosing a suitable effective macroscopic cross-section (equivalent to choosing an effective mean free path). It is by introducing such a scale length that we adapt the results of Case et al.[2] to accommodate non-isotropic scattering through use of the transport cross-section. We first discuss the scale length used with $\kappa_o(c)$ and then that with $\lambda(c)$.

We assume that the dimensioned (1/km) diffusion length, K, and $\kappa_o(c)$ are related by the expression

$$K = \kappa_o(c)\, \sigma \tag{5}$$

where σ is an effective macroscopic cross-section (or inverse mean free path) whose precise form will be established below. We determine σ by the requirement that the diffusion coefficient, D, whose basic definition (Reference 1, pp. 241, 242) is

$$D = \Sigma_a/K^2 \quad , \tag{6}$$

approach its anisotropic-scattering asymptotic value of $(3\Sigma_{tr})^{-1}$ (cf. Reference 1 pp. 196, 197) in the limit that Σ_a approaches zero. To determine σ, we first introduce the usual relation between the total, scattering, and absorption cross-sections,

Table A-1. Values of κ_o and λ[a].

c	κ_o	λ
0.0	1.000000	1.0000
0.1	1.000000	1.0000
0.2	0.999909	0.9993
0.3	0.997414	0.9889
0.4	0.985624	0.9606
0.5	0.957504	0.9201
0.6	0.907332	0.8750
0.7	0.828635	0.8300
0.8	0.710412	0.7871
0.9	0.525430	0.7472
0.92	0.474002	
0.94	0.413976	
0.96	0.340829	
0.98	0.242983	
0.99	0.172511	
1.00	0.000000	0.7104

[a] From Tables 8 and 23 of Case et al.[2]

$$\Sigma_a = \Sigma - \Sigma_s \quad , \tag{7}$$

and then use Equations (3), (5), (6), and (7) to obtain

$$D = \frac{(1-c)\Sigma}{\kappa_o^2 \sigma^2} \quad . \tag{8}$$

Next, we use the fact (Reference 2, p. 58) that

$$\kappa_o^2 \rightarrow 3\,(1-c) \text{ as } c \rightarrow 1 \quad . \tag{9}$$

Thus, in order that we can have

$$D \to \frac{1}{3\Sigma_{tr}} \text{ as } c \to 1 \quad , \tag{10}$$

we must have

$$\frac{\Sigma}{\sigma^2} = \frac{1}{\Sigma_{tr}} \tag{11a}$$

or

$$\boxed{\sigma^2 = \Sigma\Sigma_{tr}} \quad . \tag{11b}$$

By collating our results thus far, we have, first of all, the general relation from the usual definition of flux,

$$b = D/2 \quad . \tag{12}$$

Then, by combining Equations (8) and (11b), we have

$$D = \frac{1-c}{\kappa_o{}^2 \Sigma_{tr}} \tag{13}$$

and from Equations (5) and (11b) we have

$$K = \kappa_o \sqrt{\Sigma\Sigma_{tr}} \quad . \tag{14}$$

We shall now relate σ, given by Equation (11b), and the parameter $\lambda(c)$. But first, we note that the use of the linear extrapolation length $\lambda(c)$ implies that the relation between ϕ and the normal component of the gradient of ϕ shall be that of the result for a semi-infinite medium, where the value of $\lambda(c)$ is determined by relating the diffusion solution to the exact transport solution.

We now assume that the dimensioned (km) linear extrapolation length, d, and $\lambda(c)$ are related by the expression

$$d = \lambda(c)/\sigma \quad . \tag{15}$$

From the definition of the linear extrapolation length, d (cf. Reference 1, pp. 199, 261), and the relation for the photon current, we must have

$$d = b/a \quad . \tag{16}$$

Thus, from Equations (16), (15), and (5) we have

$$a = \frac{b\sigma}{\lambda(c)} = \frac{bK}{\lambda(c)\kappa_o(c)} \quad . \tag{17}$$

To summarize our parameter evaluation, we have:

1. $c = \Sigma_s/\Sigma$, dimensionless, Equation (3)

2. $\kappa_o(c)$, $\lambda(c)$ from tables

3. $D = \dfrac{1-c}{\kappa_o^2(c)\Sigma_{tr}}$ km, Equation (13)

4. $K = \kappa_o(c)\sqrt{\Sigma\Sigma_{tr}}$, km^{-1}, Equation (14)

5. $b = D/2$, km, Equation (12)

6. $a = \dfrac{bK}{\kappa_o(c)\lambda(c)}$, dimensionless, Equation (17)

An examination of the values for $\kappa_o(c)$ and $\lambda(c)$ in Table A-1 shows that

$$\frac{bK}{a} = \kappa_o(c)\lambda(c) \leq 1 \quad . \tag{18}$$

Thus, the factor $[(a/bK) - bK/a]$, which occurs in the diffusion solutions to be developed later, has the very important feature of never being negative.

The diffusion parameters for both the "standard" usage and our adopted usage, as well as their values in the limiting cases $c = 0,1$, are given in Table A-2. That the limiting values are valid for $c \to 0$ (pure absorption) can be seen by considering the pure absorption solution for a semi-infinite medium, $\exp(-\Sigma_a Z)$. The positive-direction photon current is just $\exp(-\Sigma_a Z)$, the negative-direction current is 0. For $c \to 1$ (pure scattering), note that for the parameter a, our limiting value differs somewhat from the usual one.

In the code, the variables a,b, and K are known as DALFA, DBETA, and DKAPPA, respectively.

A-2 SINGLE-LAYER PLANAR SLABS

The first problem to be considered is diffusion in a single layer of finite thickness. The sequence of problems is from the simplest to the more complicated. Time-independent problems are treated before time-dependent ones, one-dimensional problems before two-dimensional ones. This sequence has value both from the standpoint of gradually increasing mathematical complexity and from the fact that the simpler solutions can serve as limiting-case checks on the more complicated solutions.

A-2.1 Steady-State Problems

The first category of problems is steady state, hence time-independent. They are of intrinsic value and also serve as checks on later time-dependent problems.

A-2.1.1 Plane Source, Surface Deposition. A slab of thickness L has unit flux per unit area incident on the lower surface ($Z = 0$), no flux incident on the upper surface. The transmitted and reflected fluxes are sought. This yields the equation for ϕ:

$$\partial^2\phi(Z)/\partial Z^2 - K^2 \phi(Z) = 0 \tag{19}$$

with $K^2 = \Sigma_a/D$ for the standard usage and $K^2 = K_o{}^2(c)\Sigma\Sigma_{tr}$ for our adopted usage. The boundary conditions are:

$$J_+(0) = 1 \tag{20a}$$

$$J_-(L) = 0 \ . \tag{20b}$$

Table A-2. Summary of Diffusion Parameters.

Parameter and Units	"Standard" Usage	"Standard" Usage Limiting Cases $c \to 0$	$c \to 1$	Our Adopted Usage	Our Usage Limiting Cases $c \to 0$	$c \to 1$
Σ, km^{-1}	$\Sigma_a + \Sigma_s$	Σ_a	Σ_s	$\Sigma_a + \Sigma_s$	Σ_a	Σ_s
Σ_{tr}, km^{-1}	$\Sigma-\bar{\mu}\Sigma_s$	Σ_a	$\Sigma_s(1-\bar{\mu})$	$\Sigma-\bar{\mu}\Sigma_s$	Σ_a	$\Sigma_s(1-\bar{\mu})$
K, km^{-1}	$\sqrt{\Sigma_a/D}$	∞	0	$\kappa_o(c)\sqrt{\Sigma\Sigma_{tr}}$	Σ_a	0
D, km	$\Sigma_s/(3\Sigma\Sigma_{tr})$	0	$1/(3\Sigma_{tr})$	$(1-c)/(\kappa_o^2(c)\Sigma_{tr})$	$1/\Sigma_a$	$1/(3\Sigma_{tr})$
b, km	D/2	0	$1/(6\Sigma_{tr})$	D/2	$1/(2\Sigma_a)$	$1/(6\Sigma_{tr})$
a, unitless	$\Sigma_s/(4\Sigma)$	0	1/4	$bK/(\kappa_o(c)\lambda(c))$	1/2	$1/(6(0.71)\sqrt{1-\bar{\mu}})$
				$\kappa_o^2(c)$	1	$3(1-c)$
				$\lambda(c)$	1	0.7104
σ, km^{-1}				$\sqrt{\Sigma\Sigma_{tr}}$	Σ_a	$\Sigma_s\sqrt{1-\bar{\mu}} \equiv \Sigma_{tr}/\sqrt{1-\bar{\mu}}$

The reflected flux is $J_-(0)$, the transmitted flux is $J_+(L)$. Solution of this problem by elementary methods yields expressions for these quantities.

$$J_+(L) = \left(\cosh KL + \tfrac{1}{2}\left(\frac{a}{Kb} + \frac{bK}{a}\right)\sinh KL\right)^{-1} \tag{21a}$$

$$J_-(0) = \tfrac{1}{2}\left(\frac{a}{Kb} - \frac{Kb}{a}\right)\sinh KL \; J_+(L) \quad . \tag{21b}$$

There are several comments to be made about this solution. The condition of small absorption shows up here immediately. For $J_-(0)$ to be a positive quantity (as it should) it is necessary that $K < a/b$. This condition is met for the "standard"-usage parameters if the absorption is small. For our adopted parameters (see Section A-1.2), this condition is always met. Secondly, in the limit of no absorption ($K \to 0$), the sum of the transmitted and reflected fluxes is unity, as it should be. A small effort, and using $b=D/2$, gives the result that

$$J_+(L) + J_-(0) + \int_0^L \Sigma_a \phi(Z)dZ = 1 \quad .$$

Finally, it can easily be shown that $J_+(L) \leq e^{-KL}$, the defect being due to increased loss in multiple collisions.

A-2.1.2 <u>Plane Source, Surface Deposition (alternate treatment)</u>. In Section A-2.1.1 the problem of flow through a slab was treated purely in the diffusion approximation. An alternate approach, based on physical considerations, separates the flux into two parts, that which has had no collisions and the remainder. This leads to an equation for the scattered flux with a source term coming from first collisions. The equation to be solved is

$$D\frac{\partial^2\phi}{\partial Z^2} - \Sigma_a\phi + \Sigma_s e^{-\Sigma Z} = 0 \quad . \tag{22}$$

The source term reflects the exponential decrease in the unscattered flux and the fact that only the scattering (not the absorption) contributes to the source. If $J_\pm$ is now considered as applying to only the scattered flux, the appropriate boundary conditions are that there be no flux incident on the slab surfaces:

$$J_+(0) = J_-(L) = 0 \quad . \tag{23}$$

The solution of this system follows the usual lines. A particular solution of the inhomogeneous equation is

$$C\,e^{-\Sigma Z},\; C = \Sigma_s D^{-1}(K^2-\Sigma^2)^{-1}$$

where K^2 is given as before. To this is added a general solution of the homogeneous equation.

$$\phi(Z) = C\,e^{-\Sigma Z} + Ae^{KL} + Be^{-KL} \quad .$$

The values of A and B are determined from the boundary conditions. The quantities of interest, the transmitted flux, $J_+(L)$, and the reflected flux, $J_-(0)$, can then be evaluated. The quantities now include unscattered flux.)

$$J_+(L) = e^{-\Sigma L}\left\{1 + C(a+b\Sigma) + \frac{\frac{C(a-b\Sigma)}{2}\left(\frac{a}{bK} - \frac{bK}{a}\right)\sinh KL}{\text{den}}\right\} \tag{24a}$$

$$- \frac{C(a+b\Sigma)}{\text{den}}$$

$$J_-(0) = C\left\{a-b\,\Sigma - \frac{e^{-\Sigma L}\,(a-b\Sigma) + \frac{a+b\Sigma}{2}\left(\frac{a}{bK} - \frac{bK}{a}\right)\sinh KL}{\text{den}}\right\} \tag{24b}$$

$$\text{den} = \cosh KL + \tfrac{1}{2}\left(\frac{a}{bK} + \frac{bK}{a}\right)\sinh KL \;. \tag{24c}$$

An interesting check on this solution can be made by letting the deposition occur in a thin layer ($\Sigma\to\infty$, Σ_s/Σ finite, with a, b, and K unchanged). The resulting limits,

$$J_+(L) \to \frac{\Sigma_s/\Sigma}{2(\text{den})}$$

$$J_-(0) \to \frac{\Sigma s}{2\Sigma}\left\{1 + \tfrac{1}{2}\left(\frac{a}{bK} - \frac{bK}{a}\right)\sinh KL/(\text{den})\right\} \;,$$

can be interpreted (using Equations (21a) and (21b) as a surface source of strength Σ_s/Σ, half entering the medium and being transmitted and reflected according to the prescription of Section A-2.1, and half being emitted outward immediately.

A-2.1.3 <u>External Point Source, Surface Deposition</u>. A slab of thickness L is illuminated by an isotropically emitting point source at a distance h below the slab. The relevant equations are:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\,\frac{\partial\phi(r,Z)}{\partial r}\right) + \frac{\partial^2\phi(r,Z)}{\partial Z^2} - K^2\phi(r,Z) = 0 \tag{25a}$$

inside the slab, with boundary conditions

$$J_+(r,0) = \frac{Q}{2\pi}\,\frac{h}{(r^2+h^2)^{3/2}} \tag{25b}$$

$$J_-(r,L) = 0 \tag{25c}$$

$$\int_0^\infty J_+(r,0)\,2\pi r dr = Q \quad .$$

Thus Q is the total flux into the slab. This is just <u>half</u> of the total flux emitted by the source.

The solution uses standard methods, although not as elementary as the method of Sections A-2.1.1 and A-2.1.2. As a first step, the problem is reduced to a one-dimensional problem by introducing the Hankel transform.[3]

$$\overline{\phi}(p,Z) = \int_0^\infty \phi(r,Z)\, J_0(pr) r dr \tag{26a}$$

$$\boxed{\phi(r,Z) = \int_0^\infty \overline{\phi}(p,Z)\, J_0(pr) p dp \quad .} \tag{26b}$$

Equation (25a) is multiplied by $rJ_0(pr)$ and integrated. The term involving radial derivatives is integrated by parts twice. Assuming $r^2\phi$ and $(\partial\phi/\partial r)r$ being zero at $r = 0$ and $r^{3/2}\phi$ and $r^{3/2}\partial\phi/\partial r$ being zero at $r = \infty$ then yields the relation

$$\frac{\partial^2 \bar{\phi}(p,Z)}{\partial Z^2} - k^2 \bar{\phi}(p,Z) = 0 \tag{27a}$$

with

$$k^2 = p^2 + K^2 .$$

The corresponding boundary conditions are, using Equations 13.51(5) and 3.7(13) of Reference 4,

$$\overline{J_+}(p,0) = \frac{Q}{2\pi} e^{-ph} \tag{27b}$$

$$\overline{J_-}(p,L) = 0 \tag{27c}$$

$$\overline{J_\pm}(p,Z) = a \bar{\phi}(p,Z) \mp b \frac{\partial\bar{\phi}(p,Z)}{\partial Z} . \tag{27d}$$

The solution of these equations follows the pattern of Sections A-2.1.1 and A-2.1.2.

$$\overline{J_+}(p,Z) = \frac{Q}{2\pi} e^{-ph} \frac{\cosh k(L-Z) + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh k(L-Z)}{\cosh kL + \frac{1}{2}\left(a/kb + \frac{kb}{a}\right) \sinh kL} \tag{28a}$$

$$\overline{J_-}(p,Z) = \frac{Q}{2\pi} e^{-ph} \frac{\frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh k(L-Z)}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} . \tag{28b}$$

These relations then give the Hankel transforms of the transmitted and reflected fluxes:

$$\boxed{\overline{J_+}(p,L) = \frac{Q}{2\pi} e^{-ph} \Big/ \left[\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL\right]} \tag{29a}$$

$$\overline{J_-}(p,0) = \frac{\frac{Q}{2\pi} e^{-ph} \frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh kL}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} . \tag{29b}$$

The actual transmitted and reflected fluxes are evaluated as integrals using Equation (26b):

$$\boxed{J_+(r,L) = \frac{Q}{2\pi} \int_o^\infty \frac{e^{-ph} J_o(pr)\, p}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL}\, dp} \tag{30a}$$

$$J_-(r,0) = \frac{Q}{2\pi} \int_o^\infty \frac{e^{-ph} J_o(pr)\, p\, \frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh kL}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL}\, dp \tag{30b}$$

$$\boxed{k^2 = p^2 + K^2;}\quad K^2 = \Sigma_a/D \quad . \tag{30c}$$

A number of quantities can be derived from these accumulated results. The total transmitted and reflected fluxes are easily obtained.

$$\boxed{\int_o^\infty J_+(r,L)\, 2\pi r dr = 2\pi\, \overline{J}_+(0,L) = \frac{Q}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right) \sinh KL}} \tag{31a}$$

$$\int_o^\infty J_-(r,0)\, 2\pi r dr = 2\pi\, \overline{J}_o(0,0) = \frac{Q\, \frac{1}{2}\left(\frac{a}{Kb} - \frac{Kb}{a}\right) \sinh KL}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right) \sinh KL} \ . \tag{31b}$$

These are just the results (adjusted for flux Q incident) of Equations (21a) and (21b). A quantity of some interest is the flux from a strip of width x_o, with one edge going through $r = 0$. Let J_{s+} be the result for the transmitted flux.

$$J_{s+} = \int_0^{x_0} dx \int_{-\infty}^{\infty} dy \; J_+ \left(\sqrt{x^2+y^2}, L\right) \tag{32a}$$

$$= \frac{Q}{\pi} \int_0^{\infty} dp \left(\frac{p \; e^{-ph}}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} \right) \times$$

(32b)

$$\int_0^{x_0} dx \int_0^{\infty} dy \; J_0\left(p\sqrt{x^2+y^2}\right) .$$

By Equations 13.47 (5) and 3.4 (6) of Reference 4, the y-integral is

$$\int_0^{\infty} dy \; J_0(p\sqrt{x^2+y^2}) = \frac{2^{-\frac{1}{2}} \, \Gamma(\frac{1}{2})}{p^{\frac{1}{2}} x^{\frac{1}{2}}} J_{-\frac{1}{2}}(px)$$

$$= \sqrt{\frac{\pi x}{2p}} \sqrt{\frac{2}{\pi p x}} \cos px$$

$$= \cos px/p \quad .$$

The x-integral can be done immediately.

$$J_{s+} = \frac{Q}{\pi} \int_0^{\infty} \frac{\sin px_0}{p} \; \frac{e^{-ph}}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} \, dp \quad . \tag{33a}$$

The analogous result for the reflected flux is J_{s-}:

$$J_{s-} = \frac{Q}{\pi}\int_0^\infty \frac{\sin px_o}{p} \frac{e^{-ph}\ \frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right)\sinh kL}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right)\sinh kL}\,dp \quad . \tag{33b}$$

The limiting case as $x_o \to \infty$ can again be compared with previous results. The quantity $\sin px_o/p$ behaves as a Dirac delta-function (see Reference 5, p. 29, Equation (47)).

$$\lim_{x_o \to \infty} \frac{\sin p\, x_o}{p} = \pi\ \delta(p)$$

$$\lim_{x_o \to \infty} J_{s+} = \frac{Q}{2} \frac{1}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{bK}{a}\right)\sinh KL}$$

$$\lim_{x_o \to \infty} J_{s-} = \frac{Q}{2} \frac{\frac{1}{2}\left(\frac{a}{Kb} - \frac{Kb}{a}\right)\sinh KL}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right)\sinh KL} \quad .$$

These are just half the results in (31a) and (31b) as they should be.

A-2.1.4 <u>Internal Point Source</u>. A slab of thickness L is illuminated by an isotropic point source located a distance h (<L) above its lower surface (Z = 0). The relevant system of equations to be solved are

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\,\frac{\partial\phi(r,Z)}{\partial r}\right) + \frac{\partial^2\phi(r,Z)}{\partial Z^2} - K^2\phi(r,Z) + \delta(\vec{r}-\hat{Z}h)/D=0 \tag{34a}$$

where $\hat{Z}$ is a unit vector in the Z direction, and

$$J_+(r,0) = J_-(r,L) = 0 \quad . \tag{34b}$$

The delta-function part of ϕ can be removed by introducing the infinite medium solution, $G(\vec{r},\vec{r}_o)$, where $\vec{r}_o = \hat{Z}\,h$.

$$G(\vec{r},\vec{r}_o) = \frac{1}{4\pi D} \frac{e^{-K|\vec{r}-\vec{r}_o|}}{|\vec{r}-\vec{r}_o|} . \qquad (35)$$

It is easy to show, by differentiation, that G satisfies Equation (34a) except where $\vec{r}=\vec{r}_o$. To evaluate the behavior at $\vec{r}_o$, the usual path of integration over a small sphere, centered at $\vec{r}_o$, is taken. Let T be the sphere volume, Σ its surface, $\rho = |\vec{r}-\vec{r}_o|$, and $d\Omega$ an element of solid angle.

$$\int_T (\text{div grad } G-K^2G)\, d\tau$$

$$= \int_\Sigma \text{grad } G\cdot d\sigma - K^2 \int_T G\, dt$$

$$= \int \frac{1}{4\pi D} e^{-K\rho} \left(\frac{-K}{\rho} - \frac{1}{\rho^2}\right) \rho^2 d\Omega - K^2 \int \frac{1}{4\pi D} \frac{e^{-K\rho}}{\rho} \rho^2 d\Omega d\rho$$

$$\xrightarrow[\rho\to o]{} \frac{-1}{4\pi D} \int d\Omega \quad .$$

If $\vec{r}_o$ is an interior point, $\int d\Omega$ is 4π. Hence $\int_T (\text{div grad } G - K^2G + \frac{1}{D}\,\delta(\vec{r}-\vec{r}_o))\, d\tau = -\frac{1}{D} + \frac{1}{D} = 0$. Using these results the solution for ϕ consists of two parts, G and ψ, where ψ satisfies the homogeneous part of the equation.

$$\phi(r,Z) = G(r,Z) + \psi(r,Z) \qquad (36a)$$

$$G(r,Z) = \frac{1}{4\pi D} \frac{e^{-K\sqrt{r^2+(Z-h)^2}}}{\sqrt{r^2+(Z-h)^2}} \qquad (36b)$$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\, \frac{\partial\psi(r,Z)}{\partial r}\right) + \frac{\partial^2\psi(r,Z)}{\partial Z^2} - K^2\psi(r,Z) = 0 \qquad (36c)$$

$$J_{\pm}(r,Z) = a\,\psi(r,Z) \mp b\,\frac{\partial\psi(r,Z)}{\partial Z} + aG(r,Z) \mp b\,\frac{\partial G(r,Z)}{\partial Z} \quad . \tag{36d}$$

As in the previous section, this is solved using Hankel transforms.

$$\overline{\psi}(p,Z) = \int_0^\infty \psi(r,Z)\, J_0(pr)\, r\, dr \tag{37a}$$

$$\frac{\partial^2\overline{\psi}(p,Z)}{\partial Z^2} - k^2\, \overline{\psi}(p,Z) = 0 \tag{37b}$$

$$k^2 = K^2 + p^2 \quad . \tag{37c}$$

The transformed boundary conditions are

$$a\,\overline{\psi}(p,L) + b\,\frac{\partial\overline{\psi}(r,Z)}{\partial Z}\bigg|_{Z=L} = -\,a\overline{G}(p,L) - b\,\frac{\partial\overline{G}(p,Z)}{\partial Z}\bigg|_{Z=L} \tag{38a}$$

$$a\,\overline{\psi}(p,0) - b\,\frac{\partial\overline{\psi}(p,Z)}{\partial Z}\bigg|_{Z=0} = -\,a\overline{G}(p,0) + b\,\frac{\partial\overline{G}(p,Z)}{\partial Z}\bigg|_{Z=L} \tag{38b}$$

$$\overline{G}(p,Z) = \int_0^\infty \frac{1}{4\pi D}\, \frac{e^{-K\sqrt{r^2 + (Z-h)^2}}}{\sqrt{r^2 + (Z-h)^2}}\, J_0(pr)\, rdr \quad .$$

This integral can be evaluated using Equation 13.47(2) of Reference 4 in a manner analogous to the derivation there of Equation 13.47(4):

$$\bar{G}(p,Z) = \frac{e^{-k|Z-h|}}{4\pi D\ k} \tag{39a}$$

$$\frac{\partial \bar{G}(p,Z)}{\partial Z} = -\frac{e^{-k|Z-h|}}{4\pi D} \frac{Z-h}{|Z-h|} \quad . \tag{39b}$$

The solution desired then leads to the result, using b = D/2:

$$\boxed{\begin{aligned} \bar{J}_+(p,L) = &\left\{\frac{(bk-a)}{16\pi\ ab^2k^2\left(\cosh kL + \frac{1}{2}\left(\frac{a}{bk} + \frac{bk}{a}\right)\sinh kL\right)} \times \right. \\ &\times [(a-bk)\ (a \sinh kh + bk \cosh kh) \\ &\left. + (a+bk)e^{-kL}(a \sinh k(L-h) + bk \cosh k(L-h))]\right\} \\ &+ e^{-k(L-h)}(a + bk)/8\pi bk \end{aligned}} \tag{40a}$$

$$\begin{aligned} \bar{J}_-(p,0) = &\left\{\frac{(bk-a)}{16\pi\ ab^2k^2\left(\cosh kL + \frac{1}{2}\left(\frac{a}{bk} + \frac{bk}{a}\right)\sinh kL\right)} \times \right. \\ &\times [(a+bk)\ (a \sinh kh + bk \cosh kh)\ e^{-kL} \\ &\left. + (a-bk)(a \sinh k(L-h) + bk \cosh k(L-h))]\right\} \\ &+ e^{-kh}(a + bk)/8\pi bk \quad . \end{aligned} \tag{40b}$$

The evaluation of the actual transmitted fluxes is achieved as in Section A-2.1.3. If desired the second term in each of the expressions can be explicitly integrated. Using Equations 3.71(13) and 13.47(2) of Reference 4,

$$\frac{\int_o^\infty e^{-h\sqrt{p^2+K^2}}\, J_o(pr)pdp}{\sqrt{p^2+K^2}} = \frac{e^{-K\sqrt{h^2+r^2}}}{\sqrt{h^2+r^2}} \tag{41a}$$

$$\int_o^\infty e^{-h\sqrt{p^2+K^2}}\, J_o(pr)pdp = \frac{he^{-K\sqrt{h^2+r^2}}}{h^2+r^2}\left(K + \frac{1}{\sqrt{h^2+r^2}}\right) . \tag{41b}$$

However, from a computational viewpoint, the convergence of the integral over p should be improved by not separating these terms. A cursory examination indicates convergence for J_+ to be as $e^{-k(L-h)}$ if separation is done, as $e^{-k(L-h)}/k$ if no separation is done.

As was done in Section A-2.1.3, the integrals over a strip can be found.

$$J_{s+} = 2\int_o^\infty \frac{\sin px_o}{p}\, \overline{J}_+(p,L)dp \tag{42a}$$

$$J_{s-} = 2\int_o^\infty \frac{\sin px_o}{p}\, \overline{J}_-(p,0)dp \quad . \tag{42b}$$

Similarly, for total fluxes out,

$$\int_o^\infty J_+(r,L)\; 2\pi r\; dr = 2\pi\; \overline{J}_+(0,L) \tag{43a}$$

$$\int_o^\infty J_-(r,0)\; 2\pi r\; dr = 2\pi\; \overline{J}_-(0,0) \quad . \tag{43b}$$

A-2.2 Time-Dependent Solutions

The only time-dependent solution that is practical from a computational viewpoint is the pure diffusion problem of a plane slab illuminated by a uniform external source. The method of Laplace transforms is used. The relevant transforms are:

$$\tilde{\phi}(z,s) = \int_0^\infty \phi(z,t)e^{-st}dt \tag{44a}$$

$$\tilde{J}_{\pm}(z,s) = \int_0^\infty J_{\pm}(z,t)e^{-st}dt \tag{44b}$$

$$F(s) = \int_0^\infty f(t)e^{-st}dt \tag{44c}$$

where f(t) is the incident flux. For convolution purposes, the case of $f(t) = \delta(t)$, $F(s) = 1$, is of special interest. The equations and boundary conditions satisfied by the transforms are:

$$\frac{\partial^2 \tilde{\phi}(z,s)}{\partial Z^2} = \left(K^2 + \frac{s}{Dv}\right) \tilde{\phi}(z,s) \tag{45a}$$

$$\tilde{J}_{\pm}(z,s) = \left(a - \frac{3bs}{2v}\right) \tilde{\phi}(z,s) \mp b \frac{\partial\tilde{\phi}(z,s)}{\partial z} \tag{45b}$$

$$\tilde{J}_{-}(L,s) = 0; \; \tilde{J}_{+}(0,s) = F(s) \quad . \tag{45c}$$

Proceeding in a straightforward way,

$$\tilde{J}_{+}(L,s) = F(s)/G(\lambda) \tag{46a}$$

$$\tilde{J}_{-}(0,s) = F(s) \tfrac{1}{2} \left(\frac{\alpha}{b\lambda} - \frac{b\lambda}{\alpha}\right) \sinh \lambda L/G(\lambda) \tag{46b}$$

$$G(\lambda) = \cosh \lambda L + \tfrac{1}{2} \left(\frac{\alpha}{b\lambda} - \frac{b\lambda}{\alpha}\right) \sinh \lambda L \tag{46c}$$

where

$$\lambda^2 = K^2 + s/Dv \, , \qquad \alpha = a - \frac{3}{2}\frac{bs}{v} \quad .$$

The relation to the steady-state solution is apparent, since the integral of the time-dependent solutions over time is just the value of the transform for s=0.

The actual time-dependent solution is obtained by the usual inverse Laplace transform,

$$J_{\pm}(z,t) = \frac{1}{2\pi i} \int_{-i\infty+\varepsilon}^{i\infty+\varepsilon} \tilde{J}_{\pm}(z,s) e^{st} ds \quad . \tag{47}$$

This is evaluated by contour integration, giving a sum of the residues at the poles of $\tilde{J}_{\pm}(z,s)$. These are at the zeroes of $G(\lambda)$. The exact evaluation of the zeroes is rather intractable, involving a simultaneous evaluation of the real and imaginary parts of λ. For simplicity, an approximate evaluation was used. This approximation neglected the difference between α and a. In terms of the boundary conditions, this is equivalent to neglecting the $\partial\phi/\partial t$ term, compared to ϕ, in the currents,* $J_{\pm}$. Using this approximation, the values of λ are pure imaginary. For the j^{th} root

$$\lambda_j = i\eta_j \tag{48a}$$

$$\tan \eta_j L = 2ab\eta_j (b^2\eta_j{}^2 - a^2)^{-1}, \; \eta \neq 0, j=1,2\ldots \tag{48b}$$

$$s_j = Dv(-\eta_j{}^2 - K^2) \quad . \tag{48c}$$

For the special case, $f(t) = \delta(t)$, the inverse Laplace transforms then yield:

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*Fluxes, for consistency.

$$J_+(L,t) = \sum_{j=1}^{\infty} \frac{e^{-s_j t} Dv\, \eta_j}{-i\, G'(i\eta_j)} \tag{49a}$$

$$J_-(0,t) = \sum_{j=1}^{\infty} \frac{e^{-s_j t}\, \frac{L}{2} \left(\frac{a}{b\eta_j} + \frac{b\eta_j}{a}\right) (\sin\eta_j L)\, Dv\eta_j}{-i\, G'(i\eta_j)} \tag{49b}$$

$$-iG'(i\eta_j) = L \sin \eta_j L - \tfrac{1}{2} \left(\frac{a}{b\eta_j} - \frac{b\eta_j}{a}\right) \cos \eta_j L \tag{49c}$$

$$+ \tfrac{1}{2} \left(\frac{a}{b\eta_j^{\,2}} + \frac{b}{a}\right) \sin \eta_j L \quad .$$

The error in the roots is of the order of D/L times the value of the root. Thus values of the root near zero, which dominate the late-time behavior, are reasonably well determined. The early-time behavior is less well determined. This does not seem a serious deficiency, since the diffusion model is poor for early times in any case, e.g., giving instantaneous transmission independent of thickness.

A-3 STEADY-STATE DIFFUSION FOR CONVEX BODIES

In order to evaluate the reflection and transmission by more general shapes, a numerical method has been developed which is applicable to general convex shapes. The restriction to convex bodies is to prevent one part of the body serving as a source for another part by an exterior path. The equations to be solved are

$$\nabla^2 \phi(\vec{r}) - K^2 \phi(\vec{r}) = 0 \tag{50a}$$

$$J_{\pm}(\vec{r}) = a\ \phi(\vec{r}) \mp b\ \mathrm{grad}\ \phi(\vec{r}) \cdot \hat{n}(\vec{r}) \tag{50b}$$

where, on the surface, $J_+(\vec{r})$ is the outward flux and $J_-(\vec{r})$ is the inward flux, with $\hat{n}(\vec{r})$ the outward unit vector normal to the surface.

The usual Green's function solution of this type of equation involves finding a function, $G(\vec{r},\vec{r}\,')$, which satisfies the Equation (50a) except at $\vec{r} = \vec{r}\,'$, where it has a delta function type singularity. The usual development proceeds as follows. For a volume, T, with surface Σ,

$$\int_T [G(\vec{r},\vec{r}\,')(\nabla^2\phi(\vec{r})-K^2\phi(\vec{r})) - \phi(\vec{r})(\nabla^2G(\vec{r},\vec{r}\,')-K^2G(\vec{r},\vec{r}\,')] \; d\tau$$

$$= \int_\Sigma [G(\vec{r},\vec{r}\,')\text{grad } \phi(\vec{r})\cdot\hat{n} - \phi(\vec{r}) \text{ grad } G(\vec{r},\vec{r}\,')\cdot\hat{n}] \; d\sigma \; . \qquad (51)$$

Since $\phi(\vec{r})$ satisfies Equation (50a) throughout the volume and $G(\vec{r},\vec{r}\,')$ satisfies it, except at $\vec{r} = \vec{r}\,'$, the volume integral can be shrunk to be over a sphere of arbitrarily small radius about $\vec{r}\,'$, volume T_s, surface Σ_s.

$$-\int_T \phi(\vec{r}) \; (\nabla^2G(\vec{r},\vec{r}\,') - K^2G(\vec{r},\vec{r}\,')) \; d\tau$$

$$= -\int_{T_s} \phi(\vec{r}) \; (\nabla^2G(\vec{r},\vec{r}\,') - K^2G(\vec{r},\vec{r}\,')) \; d\tau$$

$$= -\int_{T_s} [\text{div}(\phi(\vec{r}) \text{ grad}G(\vec{r},\vec{r}\,')) - \text{grad}\,\phi\,(\vec{r}) \text{ grad}G(\vec{r},\vec{r}\,') - K^2G(\vec{r},\vec{r}\,')] \; d\tau$$

$$= -\int_{\Sigma_s} \phi(\vec{r}) \text{ grad } G(\vec{r},\vec{r}\,') \cdot \hat{n}(\vec{r}) \; d\sigma$$

$$-\int_{T_s} [\text{grad}\,\phi\,(\vec{r})\cdot\text{grad}G(\vec{r},\vec{r}\,') + K^2G(\vec{r},\vec{r}\,')] \; d\tau \; .$$

Since $\nabla^2 G - K^2 G$ has an integrable singularity at $\vec{r}=\vec{r}'$, the second integral vanishes as the sphere radius goes to zero. (*Typically G is like* $|\vec{r}-\vec{r}'|^{-1}$, grad G like $|\vec{r}-\vec{r}'|^{-2}$ and $d\tau$ like $|\vec{r}-\vec{r}'|^2 d|\vec{r}-\vec{r}'|$.) In the surface integral, since $\phi(\vec{r})$ is continuous, it may be adequately approximated by $\phi(\vec{r}')$ and removed from the integral. Equation (51) can then be written as

$$-\phi(r') \lim \int_{\Sigma_s} \text{grad } G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r})\, d\sigma$$

$$= \int_{\Sigma} [G(\vec{r},\vec{r}')\,\text{grad}\phi(\vec{r})\cdot\hat{n}(\vec{r}) - \phi(\vec{r})\ \text{grad}G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r})]\, d\sigma \ . \qquad (52)$$

The limit-integral multiplying $\phi(\vec{r}')$ is here left explicit since its value depends critically on whether the point $\vec{r}'$ is inside the surface or on the surface. In the former case, the sphere radius will be small enough, in the limiting process, that the sphere surrounds the point, $\vec{r}'$. If $\vec{r}'$ is on the surface this will not happen.

In the usual textbook formulation, $G(\vec{r},\vec{r}')$ is chosen to match suitable boundary conditions, e.g., if $\hat{n}\cdot\text{grad}\,\phi$ is given on the surface, $\hat{n}\cdot\text{grad}\,G$ is zero on the surface; if ϕ is given, G is set to zero. In the method proposed here, following Banaugh,[6] the function G is taken to be the infinite medium function. The boundary conditions specify a linear relation between ϕ and $\hat{n}\cdot\text{grad}\,\phi$ on the boundary. Then, if $\vec{r}'$ is taken to be on the surface, Equation (52) is an integral equation for the *unknown values of* ϕ *or* $\hat{n}\cdot$*grad* ϕ, as desired, on the surface.

For the problem under consideration, where $\vec{\rho} = \vec{r}-\vec{r}'$ and $d\omega$ is element of solid angle, choose

$$G(\vec{r},\vec{r}') = e^{-K|\vec{r}-\vec{r}'|}\,|\vec{r}-\vec{r}'|^{-1} \qquad (53)$$

$$\lim \int_{\Sigma_s} \text{grad } G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r})\,d\sigma = \lim \int_{\Sigma_s} \frac{\partial}{\partial\rho}\,(e^{-K\rho}\ \rho^{-1})\rho^2\ d\omega$$

$$= \lim \int_{\Sigma_s} e^{-K\rho}\ (-k\rho^{-1}-\rho^{-2})\rho^2\ d\omega$$

$$= -\int_{\Sigma_s} d\omega \ .$$

Equation (52) then becomes

$$\Omega\phi(\vec{r}\,') = \int_{\Sigma} [G(\vec{r},\vec{r}\,')\mathrm{grad}\phi(\vec{r})\cdot\hat{n}(\vec{r}) - \phi(\vec{r})\mathrm{grad}G(\vec{r},\vec{r}\,')\cdot\hat{n}(\vec{r})]\, d\sigma \tag{54}$$

where Ω is the solid angle subtended by the surface at the point $\vec{r}\,'$, e.g., 4π if $\vec{r}\,'$ is inside the surface, 2π if $\vec{r}\,'$ is on the surface at a point not a "corner".

For the problem at hand, only surface values are of interest and it will be assumed the surface is "smooth." The quantity of actual interest is $J_+(\vec{r})$ with $J_-(\vec{r})$ given. On the surface

$$\phi(\vec{r}) = \frac{1}{2a}\,(J_+(\vec{r}) + J_-(\vec{r}))$$

$$\mathrm{grad}\phi(\vec{r})\cdot\hat{n} = \frac{1}{2b}\,(J_-(\vec{r}) - J_+(\vec{r}))$$

$$\frac{\pi}{a}\,(J_+(\vec{r}\,') + J_-(\vec{r}\,')) = -\int_{\Sigma}\left[\frac{1}{2a}\,(J_+(\vec{r}) + J_-(\vec{r}))\ \mathrm{grad}\ G(\vec{r},\vec{r}\,')\cdot\hat{n} - \frac{1}{2b}\,(J_-(\vec{r}) - J_+(\vec{r}))\ G(\vec{r},\vec{r}\,')\right] d\sigma$$

$$J_+(\vec{r}\,') = -J_-(\vec{r}\,') - \int_{\Sigma} J_-(r)\left[\frac{1}{2\pi}\ \mathrm{grad}\ G(\vec{r},\vec{r}\,')\cdot\hat{n} - \frac{a}{2\pi b}\,G(\vec{r},\vec{r}\,')\right] d\sigma$$
$$- \int_{\Sigma} J_+(\vec{r})\left[\frac{1}{2\pi}\ \mathrm{grad}\ G(\vec{r},\vec{r}\,')\cdot\hat{n} + \frac{a}{2\pi b}\,G(\vec{r},\vec{r}\,')\right] d\sigma\ . \tag{55}$$

The first two terms are, in principle, known, although the actual evaluation of the integral may present some problems. Thus Equation (55) is an integral equation for the values of the emergent flux, J_+, on the surface.

Computationally, the procedure for solving the equation consists of replacing the integral by a set of algebraic equations. A grid of points, $\vec{r}_j$, is established, each having an associated region, Σ_j, and a local vector, $\vec{\rho}_j$.

$$J_+(\vec{r}_j) = -J_-(\vec{r}_j) - \frac{1}{2\pi} \Sigma_{k\neq j} \int_{\Sigma_k} J_-(\vec{r}_k+\vec{\rho}_k) \left[\text{grad}_{\rho_k} G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\cdot\hat{n} - \frac{a}{b} G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\right] d\sigma_k$$

$$- \frac{1}{2\pi} \Sigma_{k\neq j} \int_{\Sigma_k} J_+(\vec{r}_k+\vec{\rho}_k) \left[\text{grad}_{\rho_k} G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\cdot\hat{n} + \frac{a}{b} G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\right] d\sigma_k$$

$$- \frac{1}{2\pi} \int_{\Sigma_j} J_-(\vec{r}_j+\vec{\rho}_j) \left[\text{grad}_{\rho_j} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n} - \frac{a}{b} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\right] d\sigma_j$$

$$- \frac{1}{2\pi} \int_{\Sigma_j} J_+(\vec{r}_j+\vec{\rho}_j) \left[\text{grad}_{\rho_j} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n} + \frac{a}{b} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\right] d\sigma_j \quad . \tag{56}$$

(grad$_{\rho_j}$ means a gradient with respect to ρ_j coordinates).

The first term is known. In the sums, $k\neq j$, the integrals may be replaced by suitable averages times the area, Σ_k. Only the last two terms require special care because of the singularity of the function G and its gradient. A demonstration that these integrals are finite and an evaluation, neglecting variation in the J's over the area, is straightforward.

$$\int_{\Sigma_j} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\, d\sigma = \int_{\Sigma_j} (e^{-K\rho_j}\, \rho_j^{\,-1})\, \rho_j d\rho_j\, d\theta$$

$$= \int_{\Sigma_j} e^{-K\rho_j}\, d\rho_j\, d\theta$$

$$\simeq 2\pi\, \tilde{\rho}_j$$

$$\simeq 2\pi \sqrt{\frac{\Sigma_j}{\pi}} \text{ (where } \pi\rho_j^{\,2} = \Sigma_j)$$

$$\simeq 2 \sqrt{\pi\Sigma_j} \tag{57}$$

$$\int_{\Sigma_j} \text{grad}\rho_j\, G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n}\, d\sigma = \int_{\Sigma_j} \frac{\partial}{\partial\rho}\left(\frac{e^{-K\rho}}{\rho}\right) \frac{\vec{\rho}\cdot\hat{n}}{\rho}\, \rho d\rho d\theta$$

$$= \int e^{-K\rho}\left(\frac{-K}{\rho} - \frac{1}{\rho^2}\right) \frac{\vec{\rho}\cdot\hat{n}}{\rho}\, \rho d\rho d\theta\ .$$

$$= \int e^{-K\rho}(-K - \frac{1}{\rho})\, \frac{\vec{\rho}\cdot\hat{n}}{\rho}\, d\rho d\theta$$

$$\frac{\vec{\rho}\cdot\hat{n}}{\rho} \simeq \frac{\rho}{2R}$$

where R is the local radius of curvature.

$$\int_{\Sigma_j} \text{grad } \rho_j\, G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n}d\sigma \simeq -\int e^{-K\rho}(K\rho+1)\, R^{-1}\, d\rho d\theta \simeq -\frac{1}{R}\sqrt{\pi\Sigma_j}\ . \tag{58}$$

Using these evaluations of the integrals then yields a set of simultaneous linear algebraic equations for the $J_+(\vec{r}_j)$.

An alternate approximate scheme can be developed which does not involve the solution of simultaneous equations, thus avoiding time consuming procedures (in the case of many points). It can best be expressed by reverting to Equation (55). Let $S(\vec{r}')$ denote the known first two terms on the right side and $G_+(\vec{r},\vec{r}')$ the multiplier of J_+ in the integral.

$$J_+(\vec{r}') = S(\vec{r}') - \int_\Sigma J_+(\vec{r})\, G_+(\vec{r},\vec{r}')\, d\sigma$$

$$J_+(\vec{r}') \left(1 + \int_\Sigma G_+(\vec{r},\vec{r}')\, d\sigma\right) = S(\vec{r}') - \int [J_+(\vec{r}) - J_+(\vec{r}')]\, G_+(\vec{r},\vec{r}')\, d\sigma \,. \tag{59}$$

This form shows some immediate advantage since the integral on the right is less singular at $\vec{r} - \vec{r}'$ due to the zero of $J_+(\vec{r}) - J_+(\vec{r}')$. The approximate procedure solves this in two successive approximations.

$$J_{1,+}(\vec{r}') = S(\vec{r}')/\left[1 + \int_\Sigma G_+(\vec{r},\vec{r}')\, d\sigma\right] \tag{60a}$$

$$J_{2,+}(\vec{r}') = J_{1,+}(\vec{r}') - \frac{\int_\Sigma \left[J_{1,+}(\vec{r}) - J_{1,+}(\vec{r}')\right] G_+(\vec{r},\vec{r}')\, d\sigma}{1 + \int_\Sigma G_+(\vec{r},\vec{r}')\, d\sigma} \,. \tag{60b}$$

The actual numerical implementation of this involves the same replacement of the integrals by sums, but each step is now explicit.

A-4 DIFFUSION THROUGH MULTIPLE SLABS

The problem of transmission by multiple contiguous plane slabs, in the pure diffusion case, can be derived from the single slab case. The case of plane source and point source follow similar development. The procedure consists in using the emerging flux from the top (bottom) of a layer as the entering flux on the bottom (top) of the next higher (lower) layer and deriving a set of relations between the surfaces.

A-4.1 Planar Diffusion Through Multiple Slabs

Assume N contiguous layers with bottoms at $d_1 < d_2 < \ldots d_N$, thickness $L_1, L_2 \ldots L_N$. In each layer,

$$\nabla^2 \phi_i(Z) - K_i^2 \phi_i(Z) = 0 \tag{61a}$$

$$J_{i,\pm}(Z) = a_i \phi_i \mp b_i \frac{\partial \phi_i}{\partial z} \quad . \tag{61b}$$

The boundary conditions are

$$J_{1,+}(d_1) = f, \; J_{N,-}(d_N + L_N) = 0 \tag{62a}$$

$$J_{i+1,\pm}(d_{i+1}) = J_{i,\pm}(d_i + L_i) \qquad i=1,2,\ldots N-1 \quad . \tag{62b}$$

The desired quantities are $J_{N,+}(d_n + L_N)$ and $J_{1,-}(d_1)$. In the ith layer

$$\phi_i(z) = A_i e^{K_i z} + B_i e^{-K_i z}$$

$$J_{i,\pm}(z) = A_i e^{K_i z} (a_i \mp b_i K_i) + B_i e^{-K_i z} (a_i \pm b_i K_i) \quad .$$

In matrix notation,

$$[J_i(d_i)] = [P_i][\overline{A}_i] \tag{63a}$$

$$[J_i(d_i + L_i)] = [P_i]\,[Q_i]\,[\overline{A}_i] \tag{63b}$$

where

$$[J_i(x)] = \begin{bmatrix} J_{i,+}(x) \\ \\ J_{i,-}(x) \end{bmatrix} \tag{63c}$$

$$[P_i] = \begin{bmatrix} a_i - b_i K_i & a_i + b_i K_i \\ \\ a_i + b_i K_i & a_i - b_i K_i \end{bmatrix} \tag{63d}$$

$$[Q_i] = \begin{bmatrix} e^{K_i L_i} & 0 \\ \\ 0 & e^{-K_i L_i} \end{bmatrix} \tag{63e}$$

$$[\overline{A}_i] = \begin{bmatrix} A_i & e^{K_i d_i} \\ \\ B_i & e^{-K_i d_i} \end{bmatrix} . \tag{63f}$$

The problem has been formulated in terms of a different set of matrices:

$$[T_i] = [R_i]\,[\overline{A}_i] \tag{64a}$$

where

$$[R_i] = \begin{bmatrix} a_i + b_i K_i & a_i - b_i K_i \\ \\ (a_i - b_i K_i)\, e^{K_i L_i} & (a_i + b_i K_i)\, e^{-K_i L_i} \end{bmatrix} \tag{64b}$$

$$[T_i] = \begin{bmatrix} J_{i,-}(d_i) \\ \\ J_{i,+}(d_i + L_i) \end{bmatrix} .$$

A recursion relation is easily developed.

$$[T_i] = [R_i]\,[\overline{A}_i] = [R_i]\,[P_i]^{-1}\,[J_i(d_i)] \quad .$$

By the boundary conditions

$$[J_i(d_i)] = [J_{i-1}(d_{i-1}+L_{i-1})] \quad ,$$

$$[T_i] = [R_i][P_i]^{-1} [P_{i-1}] [Q_{i-1}] [R_{i-1}]^{-1} [T_{i-1}]$$

$$= [M_n] [T_{i-1}]$$

$$[T_N] = [M_N] [M_{N-1}] \ \ldots \ [M_2] [T_1]$$

$$= [\mathcal{M}] [T_i]$$

$$[T_N] = [R_N] [Q_N]^{-1} [P_N]^{-1} [J_N(d_N+L_N)]$$

$$\begin{bmatrix} J_{N,-}(d_N) \\ \\ J_{N,+}(d_N+L_N) \end{bmatrix} = [R_N] [Q_N]^{-1} [P_N]^{-1} \begin{bmatrix} J_{N,+} \ (d_N+L_N) \\ 0 \end{bmatrix}$$

$$[T_1] = [R_1] [P_1]^{-1} [J_1(d_1)]$$

$$\begin{bmatrix} J_{1,-}(d_1) \\ \\ \\ J_{1,+}(d_1+L_1) \end{bmatrix} = [R_1] [P_1]^{-1} \begin{bmatrix} f \\ \\ \\ J_{1,-}(d_1) \end{bmatrix} .$$

Defining

$$\hat{D}_i = \cosh K_iL_i - \frac{1}{2}\left(\frac{a_i}{b_iK_i} + \frac{b_iK_i}{a_i}\right) \sinh K_iL_i$$

$$\lambda_i = \frac{1}{2}\left(\frac{a_i}{b_iK_i} - \frac{b_iK_i}{a_i}\right) \sinh K_iL_i$$

$$[\hat{M}_i] = [M_i]\Big/\hat{D}_{i-1} = \begin{bmatrix} 1 & -\lambda_{i-1} \\ \lambda_{i-1} & \hat{D}_i\hat{D}_{i-1}-\lambda_i\lambda_{i-1} \end{bmatrix}$$

$$[\hat{\mathcal{M}}] = [M_N]\,[M_{N-1}]\,\ldots\,[M_2] \quad ,$$

straightforward matrix operations lead to

$$J_{N,+}(d_N+L_N) = \left(\Pi_{i=1}^{N}\,\hat{D}_i\right) f\Big/\left\{[1,-\lambda_N]\,[\hat{\mathcal{M}}]\begin{bmatrix}1\\ \lambda_1\end{bmatrix}\right\} \quad . \tag{65a}$$

A similar expression can be derived for $J_{1,-}(d_1)$,

$$J_{1,-}(d_1) = \frac{f\,\hat{D}_1\,[1,-\lambda_N]\,[\hat{\mathcal{M}}]\begin{bmatrix}0\\ 1\end{bmatrix}}{[1,-\lambda_N]\,[\hat{\mathcal{M}}]\begin{bmatrix}1\\ \lambda_1\end{bmatrix}} \quad . \tag{65b}$$

Only Equation (65a) has been introduced into a computer program.

It should be noted that the requirement of contiguous layers is overly restrictive in this one-dimensional case. Actually the requirement is for non-overlapping layers,

$$d_1 \le d_1 + L_1 \le d_2 \le d_2 + L_2 \;\ldots\; \le d_N \le d_N + L_N \quad .$$

A-4.2 Point Source Diffusion Through Multiple Slabs

The slab geometry is the same as in Section A-4.1. It is essential, here, that the slabs be contiguous because of cylindrical divergence. The source is a point source at $d_o(\leq d_1)$. In the i^{th} region, the equations to be satisfied are

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\phi_i}{\partial r}\right)+\frac{\partial^2\phi_i}{\partial z^2}-K_i^2\,\phi_i=0 \tag{66a}$$

$$J_{i,\pm}(r,z)=a_i\,\phi_i\mp b_i\,\frac{\partial\phi_i}{\partial z}\quad . \tag{66b}$$

The boundary conditions are that J_+ and J_- are continuous at the boundaries and

$$J_{1,+}(r_1,d_1)=\frac{Q}{2\pi}\;\frac{d_1-d_0}{[r^2+(d_1-d_o)^2]^{3/2}}$$

$$J_{N,-}(r_1,d_N+L_N)=0\quad .$$

As in Section A-2.1.3, Hankel transforms are used. Then in the i^{th} slab

$$\frac{\partial^2\,\overline{\phi}_i(p,z)}{\partial z^2}-k_i^2\,\overline{\phi}_i(p,z)=0 \tag{67a}$$

$$k_i^2=p^2+K_i^2 \tag{67b}$$

$$\overline{J}_{i,\pm}(p,z)=a_i\,\overline{\phi}_i(p,z)\mp b_i\,\frac{\partial\overline{\phi}_i\,(p,z)}{\partial z}\quad . \tag{67c}$$

$\overline{J}_{i,+}(p,z)$ and $\overline{J}_{i,-}(p,z)$ are continuous at the interfaces and

$$\overline{J}_{1,+}(p,d_1) = \frac{Q}{2\pi} e^{-p(d_1-d_0)} = \overline{f}(p) \tag{68d}$$

$$\overline{J}_{N,-}(p,d_N+L_N) = 0 \tag{68e}$$

$$\overline{J}_{L+1,\pm}(p,d_{i+1}) = \overline{J}_{i,\pm}(p,d_i+L_i), \quad i=1,2 \ldots N-1 \quad . \tag{68f}$$

The functions of interest are $\overline{J}_{N,+}(p,d_N+L_N)$ and $\overline{J}_{1,-}(p,d_1)$. These equations are formally the same as Equations (61) and (62) in Section A-4.1, with K_i replaced by k_i and p appearing throughout as a parameter.

$$\boxed{\overline{J}_{N,+}(p,d_N+L_N) = \overline{f}(p) \prod_{i=1}^{N} \hat{D}_i \Big/ \left\{[1,-\lambda_N]\ [\hat{\mathcal{M}}] \begin{bmatrix} 1 \\ \lambda_1 \end{bmatrix}\right\}} \tag{69}$$

with

$$\overline{f}(p) = \frac{Q}{2\pi} e^{-p(d_1-d_o)}$$

$$\hat{D}_i = \cosh k_i L_i - \tfrac{1}{2}\left(\frac{a_i}{b_i k_i} + \frac{b_i k_i}{a_i}\right) \sinh k_i L_i$$

$$\lambda_i = \tfrac{1}{2}\left(\frac{a_i}{b_i k_i} - \frac{b_i k_i}{a_i}\right) \sinh k_i L_i$$

$$k_i{}^2 = K_i{}^2 + p^2$$

$$[\hat{\mathcal{M}}] = [\hat{M}_N]\ [\hat{M}_{N-1}] \ \ldots\ [\hat{M}_2]$$

$$[\hat{M}_i] = \begin{bmatrix} 1 & -\lambda_{i-1} \\ \lambda_i & \hat{D}_i \hat{D}_{i-1} - \lambda_i \lambda_{i-1} \end{bmatrix} .$$

The actual value of the emergent flux must be determined by an inversion of the Hankel transform as in Section A-2.1.3.

$$\boxed{J_{N,+}(r,d_N+L_N) = \int_o^\infty \overline{J_{N,+}}(p,d_N+L_N)\; J_o(pr)\; pdp \quad .} \qquad (70)$$

A-4.3 Diffusion Through Overlapping or Non-Contiguous Slabs

The restriction to contiguous layers of Section A-4.2 and to non-overlapping layers of Sections A-4.1 and A-4.2 can be removed in a crude approximation. The recipe proposed consists in fixing the tops of all 14 cloud types and the bottoms of the seven low-altitude cloud types, adjusting the bottoms of the remaining layers (i.e., the mid- and high-altitude cloud types) to give contiguous layers and adjusting the density of each layer to give the original optical thickness.

This procedure is admittedly crude but seems the simplest one that even approximately simulates the actual problem.

A-5 REFERENCES

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APPENDIX B

ROSCOE-IR

NATURAL CLOUD PROGRAM LISTING

```
      PROGRAM ROSCOER(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)             ROSCOER    2
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)        SORCE      2
      COMMON/ LOS /  HLOS(1,16), ULOS(1,16), VLOS(1,16), WLOS(1,16)      LOS        2
      COMMON/CLOUD/ NCLOUD,                                               CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),         CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                                CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                              PARAMS     2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                                DET        2
      COMMON /MATERL/MSM,DDM(7),SRFALT                                    MATERL     2
      COMMON/ PTE /  P1,P2,P3,P4,T1,T2,T3,T4,                             PTE        2
     1               S1,S2,S3,S4,E1,E2,E3,E4                              PTE        3
     1              ,PCFLOS                                               PTE        4
      COMMON/SOLARP/ SOLLAT,SOLLON,DUMDUM(10)                             SOLARC     2
      COMMON/INTRCPT/ ALTLK(20),THETALK(20),PHILK(20)                     INTERCPT   2
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                             ATMOSX     2
      COMMON/XX1111/  KCLDK, CLDLAM                                       ROSCOER   13
      LOGICAL  SINCLD                                                     ROSCOER   14
      DATA DTR,RTD  / .01745329251994,57.2957795131 /                     ROSCOER   15
      DATA IN/5/, IOUT/6/, PI/3.14159265/, RE/6371.03/                    ROSCOER   16
      DATA  SOLLAT, SOLLON / 0.0, -1.5708 /                               ROSCOER   17
      DATA RSUN / 1.495979E8/                                             ROSCOER   18
      DATA SRFALT / 0.0 /                                                 ROSCOER   19
C                                                                         ROSCOER   20
C        THIS IS A DRIVER PROGRAM TO CHECK OUT THE INDIVIDUAL             ROSCOER   21
C        ROUTINES                                                         ROSCOER   22
C                                                                         ROSCOER   23
C                                                                         ROSCOER   24
C        ALL DIMENSIONS IN KILOMETERS                                     ROSCOER   25
C        FIELD OF VIEW IN KILOMETERS SQUARED                              ROSCOER   26
C                                                                         ROSCOER   27
C        K IS CLOUD NUMBER                                                ROSCOER   28
C        UL,VL,WL IS LINE OF SIGHT                                        ROSCOER   29
C        ALAM IS WAVELENGTH (MICRONS)                                     ROSCOER   30
C        TCOEF IS OUTPUT TRANSFER COEFFICIENT                             ROSCOER   31
C                                                                         ROSCOER   32
C        CALL CLOUDO TO GET THE CLOUD INPUTS                              ROSCOER   33
C                                                                         ROSCOER   34
C        SPECTRAL RADIANCES ARE IN UNITS OF WATTS PER SR PER KM**2        ROSCOER   35
C        PER MICRON                                                       ROSCOER   36
C        THE TRANSFER COEFFICIENT HAS UNITS OF SR-1                       ROSCOER   37
CLJ                                                                       ROSCOER   38
CLJ       READ OR SET THE FOLLOWING PARAMETERS...                         ROSCOER   39
CLJ                                                                       ROSCOER   40
CLJ          PARAMETER  IN COMMON  DEFINED IN   READ/SET  COMMENT         ROSCOER   41
CLJ          ---------  ---------  ----------   --------  -------         ROSCOER   42
CLJ          HD         DETECT     SUB. LOS        R                      ROSCOER   43
CLJ          THETAD     DETECT     SUB. LOS        R                      ROSCOER   44
CLJ          PHID       DETECT     SUB. LOS        R                      ROSCOER   45
CLJ          FOV        DETECT     SUB. LOS        R                      ROSCOER   46
CLJ          ALAM        --        SUB. SCLOUD     R                      ROSCOER   47
CLJ          UL,VL,WL    --        SUB. SCLOUD        S                   ROSCOER   48
CLJ                                                                       ROSCOER   49
CLJ          MSM        MATERL     SUB. SCLOUD        S                   ROSCOER   50
CLJ          DDM(MSM)   MATERL     SUB. SCLOUD        S                   ROSCOER   51
CLJ          SRFALT     MATERL     SUB. SCLOUD        S        A          ROSCOER   52
CLJ                                                                       ROSCOER   53
CLJ          INFIL      PARAMS                        S        B1         ROSCOER   54
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CLJ        IOFIL      PARAMS                     S      B2        ROSCOER    55
CLJ        PI         PARAMS                     S                ROSCOER    56
CLJ        ERAD       PARAMS                     S      C         ROSCOER    57
CLJ        DGTOR      PARAMS                     S      D1        ROSCOER    58
CLJ        RTODG      PARAMS                     S      D2        ROSCOER    59
CLJ                                                               ROSCOER    60
CLJ        P1,P2      PTE         SUB. SCLOUD    S                ROSCOER    61
CLJ        P3,P4      PTE         SUB. SCLOUD    S                ROSCOER    62
CLJ                                                               ROSCOER    63
CLJ        SOLLAT     SOLARP      SUB. SCLOUD    S      E         ROSCOER    64
CLJ        SOLLON     SOLARP      SUB. SCLOUD    S      E         ROSCOER    65
CLJ                                                               ROSCOER    66
CLJ        NSORCE     SORCE       SUB. CLOUD1    S                ROSCOER    67
CLJ        HSORCE(1)  SORCE       SUB. CLOUD1  R                  ROSCOER    68
CLJ        THETAS(1)  SORCE       SUB. CLOUD1  R                  ROSCOER    69
CLJ        PHIS(1)    SORCE       SUB. CLOUD1  R                  ROSCOER    70
CLJ        WKT        --                       R        F         ROSCOER    71
CLJ        ISUN       --          SUB. SCLOUD  R                  ROSCOER    72
CLJ                                                               ROSCOER    73
CLJ        KCLDK      XX1111      SUB. CLOUD3    S                ROSCOER    74
CLJ        CLDLAM     XX1111      SUB. CLOUD3    S                ROSCOER    75
CLJ                                                               ROSCOER    76
CLJ        UL,VL,WL   --          SUB. SCLOUD    S                ROSCOER    77
CLJ        -------------------------------------------------------ROSCOER    78
CLJ        A    SET BY DATA STATEMENT                             ROSCOER    79
CLJ        B1   INPUT FILE FOR NATURAL CLOUD MODEL                ROSCOER    80
CLJ        B2   OUTPUT FILE FOR NATURAL CLOUD MODEL               ROSCOER    81
CLJ        C    EARTH RADIUS, KM                                  ROSCOER    82
CLJ        D1   DEGREES-TO-RADIANS                                ROSCOER    83
CLJ        D2   RADIANS-TO-DEGREES                                ROSCOER    84
CLJ        E    SET BY DATA STATEMENT FOR SIMPLE TEST RUNS WHEN   ROSCOER    85
CLJ             DUMMY USED FOR SUBROUTINES ATMOSU, SOLORB, ETC.   ROSCOER    86
CLJ             FOR THE REAL SUBROUTINE ATMOSU, ETC., A NUMBER    ROSCOER    87
CLJ             OF QUANTITIES MUST BE SET, FOR WHICH SEE PROGRAM  ROSCOER    88
CLJ             DRIVER FOR SUBROUTINES ATMOSU, ETC.               ROSCOER    89
CLJ        F    YIELD OF ARTIFICIAL SOURCE IN KT, USED TO GET     ROSCOER    90
CLJ             SOURCE RADIUS, BASED ON FORMULA AND ALTITUDE      ROSCOER    91
CLJ             SCALING FROM GLASSTONE (ENW).                     ROSCOER    92
CLJ                                                               ROSCOER    93
    7 CONTINUE                                                    ROSCOER    94
C                                                                 ROSCOER    95
C        READ DETECTOR AND SOURCE DATA                            ROSCOER    96
C                                                                 ROSCOER    97
   10 FORMAT(4E10.3)                                              ROSCOER    98
      READ(IN,10)HD,THETAD,PHID,FOV                               ROSCOER    99
      IF( HD.LT.0.0 )  GO TO 99                                   ROSCOER   100
      WRITE(IOUT,20) HD,THETAD,PHID,FOV                           ROSCOER   101
   20 FORMAT(*   DETECTOR LOCATION   *4E12.4)                     ROSCOER   102
      NSORCE = 1                                                  ROSCOER   103
      READ(IN,10)  HSORCE(1),THETAS(1),PHIS(1),WKT                ROSCOER   104
      CALL ATMOSU(2,HSORCE(1))                                    ROSCOER   105
      RSORCE(1) = 6.70E-02 * WKT**0.40 * (1.2250E-03/RHO)**0.333333 ROSCOER 106
      WRITE(IOUT,12)  HSORCE(1),THETAS(1),PHIS(1),WKT,RSORCE(1)   ROSCOER   107
   12 FORMAT (*0   SOURCE LOCATION,  YIELD(KT), AND  RADIUS(KM)  =*, ROSCOER 108
     1  5E12.4)                                                   ROSCOER   109
      READ(IN,14)  ISUN                                           ROSCOER   110
   14 FORMAT (I10)                                                ROSCOER   111
```

```
      WRITE(IOUT,16)  ISUN                                            ROSCOER   112
   16 FORMAT (*      ISUN = *,I2)                                     ROSCOER   113
      READ(IN,10)  ALAM                                               ROSCOER   114
      WRITE(IOUT,17)  ALAM                                            ROSCOER   115
   17 FORMAT (*      ALAM = *,E12.4)                                  ROSCOER   116
      CALL CLOUD0(MODE)                                               ROSCOER   117
      IF( MODE .NE. 0) GO TO 40                                       ROSCOER   118
C                                                                     ROSCOER   119
COMMENT   TO CHECK OUT DETERMINISTIC MODE                             ROSCOER   120
C                                                                     ROSCOER   121
      CALL POL TO CT(RE+HD,THETAD,PHID,XD,YD,ZD)                      ROSCOER   122
      IPASS = 1                                                       ROSCOER   123
   22 CONTINUE                                                        ROSCOER   124
      CALL CLOUD1                                                     ROSCOER   125
C                                                                     ROSCOER   126
      DO 30 K=1,NCLOUD                                                ROSCOER   127
      KCLDK = 99                                                      ROSCOER   128
      CLDLAM = -99.                                                   ROSCOER   129
      CALL LOS( K )                                                   ROSCOER   130
      DO 30 I=1,64                                                    ROSCOER   131
      IF( HLOS(1,I).EQ.0.0 )  GO TO 33                                ROSCOER   132
      UL = ULOS(1,I)                                                  ROSCOER   133
      VL = VLOS(1,I)                                                  ROSCOER   134
      WL = WLOS(1,I)                                                  ROSCOER   135
      CALL CLOUD2(UL,VL,WL)                                           ROSCOER   136
      CALL CLOUD3(UL,VL,WL,K,ALAM,TCOEF,TEMISS,SINCLD)                ROSCOER   137
      IF( SINCLD )  GO TO 7                                           ROSCOER   138
      WRITE(6,25)  KCLOUD(K),TCOEF,ALAM,TEMISS                        ROSCOER   139
      WRITE(6,23)                                                     ROSCOER   140
   23 FORMAT (///)                                                    ROSCOER   141
   25 FORMAT( * THE TRANSFER COEFFICIENT TO CLOUD NO.*I5* IS *E12.4* FOR ROSCOER   142
     X A *F6.2 * MICRON WAVELENGTH* /                                 ROSCOER   143
     X *   THE THERMAL EMISSION (RADIANCE) IS *E12.4 )                ROSCOER   144
   30 CONTINUE                                                        ROSCOER   145
   33 CONTINUE                                                        ROSCOER   146
      IF( (ISUN.EQ.0) .OR. (IPASS.EQ.2) )  GO TO 31                   ROSCOER   147
C         FOR THE SUN AS A SOURCE, SET...                             ROSCOER   148
      HSORCE(1) = RSUN-RE                                             ROSCOER   149
      THETAS(1) = 90. - SOLLAT*RTD                                    ROSCOER   150
      PHIS(1) = SOLLON*RTD                                            ROSCOER   151
      IPASS = 2                                                       ROSCOER   152
      GO TO 22                                                        ROSCOER   153
   40 CONTINUE                                                        ROSCOER   154
C                                                                     ROSCOER   155
COMMENT  TO CHECK OUT STATISTICAL MODE                                ROSCOER   156
C                                                                     ROSCOER   157
      KEEPSUN = ISUN                                                  ROSCOER   158
      ISUN = 0                                                        ROSCOER   159
      MSM = 1   $   DDM(1) = 0.10                                     ROSCOER   160
C         GET  A  LOS                                                 ROSCOER   161
      CALL POL TO CT(RE+HD,THETAD,PHID,XD,YD,ZD)                      ROSCOER   162
      CALL POL TO CT(RE+HSORCE(1),THETAS(1),PHIS(1),XS,YS,ZS)         ROSCOER   163
      RR = SQRT((XD-XS)**2 + (YD-YS)**2 + (ZS-ZD)**2 )                ROSCOER   164
      UL = (XS-XD)/RR  $  VL = (YS-YD)/RR  $  WL = (ZS-ZD)/RR         ROSCOER   165
      WL = SIGN ( AMIN1(ABS(WL*1.01),1.00),WL )                       ROSCOER   166
      VL = SIGN (SQRT(1. - WL**2 - UL**2),VL )                        ROSCOER   167
C                                                                     ROSCOER   168
```

```
C        THIS PRESCRIPTION WORKS ONLY FOR A PARTICULAR SET OF INPUTS
C        I.E., FOR SOURCE AND DETECTOR AT THETA=90. AND PHI=-90.
C
C        INTEGRATE OVER RADIAL DISTRIBUTION ON TOP
C        OF CLOUD TO GET TOTAL TRANSMISSION
      RSUM = 0.0
      DXX = 0.25
      DO 301 I=1,50
      X = DXX*(FLOAT(I)-0.999)
      RR = SQRT( (XD-X)**2         + (ABS(YD)-RE)**2 + ZD**2)
      UL =(X - XD ) / RR
      WL = 0.00000001
      VL = SQRT( 1. - UL**2 )
      WRITE(6,777) X
  777 FORMAT(10X,*RDIST = * E12.4)
      P1 = 0.10   $   P2 = 0.25
      P3 = 0.50   $   P4 = 0.90
      CALL SCLJUD(ALAM,UL,VL,WL,ISUN)
C
C
C        TC10 IS THE TRANSFER COEFFICIENT AT 10 PERCENT, ETC.
      RSUM = RSUM + PI*X*T4
C
      WRITE(6,26)  P1,P2,P3,P4
      WRITE(6,27)  T1,T2,T3,T4
      WRITE(6,29)  E1,E2,E3,E4
   26 FORMAT (*0    STATISTICAL CLOUDS,  P1,P2,P3,P4 =  *4F10.2)
   27 FORMAT (*     SOURCE TRANSFER CF    T1,T2,T3,T4 =  *4E10.3)
   28 FORMAT (*     SUN TRANSFER COEF     S1,S2,S3,S4 =  *4E10.3)
   29 FORMAT (*     EMISSION              E1,E2,E3,E4 =  *4E10.3)
  301 CONTINUE
      RSUM = RSUM*DXX
      WRITE(6,111)  RSUM,ALAM
  111 FORMAT (*      TOTAL TRANSMISSION FOR LAMDA IS  *,E13.5,F10.3)
C
      IF( KEEPSUN.EQ.0 )  GO TO 31
      CALL SCLJUD(ALAM,UL,VL,WL,KEEPSUN)
      WRITE(6,26)  P1,P2,P3,P4
      WRITE(6,28)  S1,S2,S3,S4
      WRITE(6,29)  E1,E2,E3,E4
   31 CONTINUE
      GO TO 7
   99 CONTINUE
      CALL EXIT
      END
```

```
      SUBROUTINE ATMOSU(JJ,ZH)                                          ATMOSU   2
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                           ATMOSX   2
CC                                                                      ATMOSU   4
CC          THIS IS A DUMMY ROUTINE REQUIRED IF THE CLOUD PACKAGE       ATMOSU   5
CC          IS EXERCISED AS A STAND-ALONE PROGRAM.                      ATMOSU   6
CC                                                                      ATMOSU   7
      TT = 288.0-6.50*ZH                                                ATMOSU   8
      RHO = 1.2250E-03 * EXP(-ZH/9.)                                    ATMOSU   9
      RETURN                                                            ATMOSU  10
      END                                                               ATMOSU  11
```

```
      FUNCTION BESSO(X)                                                 BESSO     2
C                                                                       BESSO     3
C EVALUATE BESSEL FUNCTION JO(X)-  (NBS 9.4.1,9.4.3)                    BESSO     4
C                                                                       BESSO     5
      IF(ABS(X).GT.3.0) GO TO 200                                       BESSO     6
  100 Y=X*X/9.                                                          BESSO     7
      F=1.-2.2499997*Y*(1.-.5624982*Y*(1.-.2499853*Y*(1.-.14048604*Y*   BESSO     8
     1  (1.-.0887421*Y*(1.-.0532400*Y)))))                              BESSO     9
      BESSO=F                                                           BESSO    10
      RETURN                                                            BESSO    11
  200 Y=3.0/X                                                           BESSO    12
      F=.79788456-7.7E-7*Y*(1.+7178.4416*Y*(1.+.01720881*Y*(1.-         BESSO    13
     1  14.427775*Y*(1.-.5305056*Y*(1.-.1988325*Y)))))                  BESSO    14
      THETA=X-.78539816-.04166397*Y*(1.+9.490214E-4*Y*(1.-66.40693*Y*   BESSO    15
     1  (1.-.20613315*Y*(1.+.5419492*Y*(1.-.4622098*Y)))))              BESSO    16
      BESSO=F*COS(THETA)/SQRT(X)                                        BESSO    17
      RETURN                                                            BESSO    18
      END                                                               BESSO    19
```

```
      BLOCK DATA                                                        CDATA      2
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)               CLDFREQ    2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1 XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)             CDDATA     3
      DATA ALAMT /2.00,2.50,2.55,2.65,2.75,2.85,3.20,3.50,4.00,5.00 /   CDATA      5
      DATA RAD/5.5,8.,6.5,4.5,5.,5.5,5.,4.8,6.,10.,40.,40.,40.,40. /    CDATA      6
      DATA  DNO / 30.,70.,30.,100.,150.,30.,70.,40.,70.,120.,1.0,       CDATA      7
     $           10.,0.8,2.0 /                                          CDATA      8
      DATA CLDBASE/.5,1.,4.,.3,.15,.5,1.,2.,2.,1.,10.,6.,6.,6. /        CDATA      9
      DATA  CLDTHK / 0.5,3.0,0.5,2.0,1.0,0.5,3.0,4.0,4.0,5.0,2.0,       CDATA     10
     $              4.0,3.0,4.0 /                                       CDATA     11
CCC                                                                     CDATA     12
CLJ   BLOCK DATA PROVIDES...                                            CDATA     13
CLJ     1. FOR 14 CLOUD TYPES, THEIR                                    CDATA     14
CLJ          A. BASE ALTITUDE,                                          CDATA     15
CLJ          B. THICKNESS,                                              CDATA     16
CLJ          C. WATER DROPLET RADIUS,                                   CDATA     17
CLJ          D. WATER DROPLET DENSITY, AND                              CDATA     18
CLJ          E. OPTICAL SCATTERING PROPERTIES (EXTINCTION AND           CDATA     19
CLJ             SCATTERING CROSS-SECTIONS AND MEAN COSINE OF            CDATA     20
CLJ             SCATTERING ANGLE) AT 10 WAVELENGTHS IN THE 2- TO        CDATA     21
CLJ             5-MICRON RANGE.                                         CDATA     22
CLJ     2. FOR REGIONS 4 AND 11 IN THE NASA CLOUD-DATA BASE,            CDATA     23
CLJ          A. THE STATISTICAL-CLOUD INDEX,                            CDATA     24
CLJ          B. OCCURRENCE FREQUENCIES OF CLOUD TYPES, AND              CDATA     25
CLJ          C. OCCURRENCE FREQUENCIES OF NUMBER OF CLOUD LAYERS.       CDATA     26
CCC                                                                     CDATA     27
CLJ   VARIABLES IN CDDATA COMMON                                        CDATA     28
CLJ          ALAMT(I) = WAVELENGTHS AT WHICH OPTICAL PROPERTIES ARE     CDATA     29
CLJ                     TABULATED, MICRONS                              CDATA     30
CLJ        SIGT(I,K) = TOTAL MICROSCOPIC EXTINCTION CROSS-SECTION AT    CDATA     31
CLJ                    WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2  CDATA     32
CLJ        SIGS(I,K) = MICROSCOPIC SCATTERING CROSS-SECTION AT          CDATA     33
CLJ                    WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2  CDATA     34
CLJ             W(I) = (NORMALIZED) CONTRIBUTION OF SPECULARLY-         CDATA     35
CLJ                    REFLECTED RADIATION TO SCATTERED RADIATION WITH  CDATA     36
CLJ                    THE DIFFRACTED RADIATION CONTRIBUTING UNITY.     CDATA     37
CLJ                    USED ONLY FOR THE LARGE-PARTICLE-SIZE CLOUDS,    CDATA     38
CLJ                    TYPES 11 THROUGH 14.  (DIMENSIONLESS)            CDATA     39
CLJ      XMUBAR(I,K) = AVERAGE COSINE OF SCATTERING ANGLE AT            CDATA     40
CLJ                    WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K             CDATA     41
CLJ           DNO(K) = NUMBER DENSITY OF WATER DROPLETS IN              CDATA     42
CLJ                    CLOUD-TYPE K, 1/CM**3                            CDATA     43
CLJ           RAD(K) = MEAN RADIUS OF WATER DROPLETS IN                 CDATA     44
CLJ                    CLOUD-TYPE K, MICRONS                            CDATA     45
CLJ       CLDBASE(K) = ALTITUDE ABOVE EARTH SURFACE OF BASE OF          CDATA     46
CLJ                    CLOUD-TYPE K, KM                                 CDATA     47
CLJ        CLDTHK(K) = THICKNESS OF CLOUD-TYPE K, KM                    CDATA     48
CCC                                                                     CDATA     49
CLJ                 FOR ABOVE VARIABLES   I=1,10  AND  K=1,14           CDATA     50
CCC                                                                     CDATA     51
CLJ   VARIABLES IN CLDFREQ COMMON                                       CDATA     52
CLJ       KMODEL = INDEX (1,11) CHARACTERIZING A SET OF STATISTICAL     CDATA     53
CLJ                AVERAGES OF CLOUD-COVERAGE CATEGORIES, CLOUD TYPES,  CDATA     54
CLJ                AND NUMBER OF CLOUD LAYERS FOR A GIVEN GEOGRAPHIC    CDATA     55
CLJ                REGION.  CHARACTERIZES A SPECIFICATION OF            CDATA     56
CLJ                CCOVER(5,11) AND CFREQ(17,4,11) IN BLOCK DATA FOR    CDATA     57
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CLJ           KMODEL=1,10.  USER MUST SUPPLY HIS OWN DATA            CDATA  58
CLJ           FOR KMODEL=11.                                         CDATA  59
CLJ     CCOVER(ICC,KMODEL) = FRACTIONAL OCCURRENCE FREQUENCY OF      CDATA  60
CLJ                          CLOUD-COVERAGE CATEGORY ICC FOR GIVEN   CDATA  61
CLJ                          KMODEL.  ICC=1,5  KMODEL=1,11           CDATA  62
CLJ        FOR  ICC=1,  CLOUD-COVERAGE FRACTION = 0.0                CDATA  63
CLJ        FOR  ICC=2,  CLOUD-COVERAGE FRACTION = 0.3                CDATA  64
CLJ        FOR  ICC=3,  CLOUD-COVERAGE FRACTION = 0.5                CDATA  65
CLJ        FOR  ICC=4,  CLOUD-COVERAGE FRACTION = 0.8                CDATA  66
CLJ        FOR  ICC=5,  CLOUD-COVERAGE FRACTION = 1.0                CDATA  67
CCC                                                                  CDATA  68
CLJ           FOR  ICC-1=IC=2,5  AND  KMODEL=KM=1,11  WE HAVE        CDATA  69
CCC                                                                  CDATA  70
CLJ     CFREQ(K,IC,KM) = FRACTIONAL OCCURRENCE FREQUENCY OF          CDATA  71
CLJ                      CLOUD-TYPE K FOR GIVEN ICC AND KMODEL.      CDATA  72
CLJ       SUM( CFREQ(K,IC,KM), K=1,14) = 1.0                         CDATA  73
CCC                                                                  CDATA  74
CLJ             CFREQ(15,IC,KM) = FREQUENCY OF ONE LAYER             CDATA  75
CLJ             CFREQ(16,IC,KM) = FREQUENCY OF TWO LAYERS            CDATA  76
CLJ             CFREQ(17,IC,KM) = FREQUENCY OF THREE LAYERS          CDATA  77
CLJ       SUM( CFREQ(L,IC,KM), L=15,17) = 1.0                        CDATA  78
CCC                                                                  CDATA  79
CLJ    DATA FOR SIGT(I,K) AND SIGS(I,K) FOR K=11,12,13,14 ARE DUMMY  CDATA  80
CLJ    DATA SINCE THEY ARE OVERRIDDEN IN SUBROUTINES DIFFUS AND      CDATA  81
CLJ    DIFPRM BY USE OF THE SMALL-WAVELENGTH APPROXIMATION           CDATA  82
CLJ          SIGT(I,K) = 2.*PI*RAD(K)**2                             CDATA  83
CLJ          SIGS(I,K) = 0.5*(1.+W(I))*SIGT(I,K)                     CDATA  84
CLJ                                                                  CDATA  85
      DATA SIGT  /232.,210.,246.,318.,269.,224.,233.,224.,247.,325., CDATA  86
     U            469.,481.,469.,539.,536.,469.,483.,492.,492.,503., CDATA  87
     U            309.,282.,283.,438.,382.,307.,318.,334.,289.,394., CDATA  88
     U            151.,173.,200.,197.,167.,156.,160.,157.,205.,229., CDATA  89
     U            202.,213.,222.,255.,227.,202.,209.,218.,230.,257., CDATA  90
     U            232.,210.,246.,318.,269.,224.,233.,224.,247.,325., CDATA  91
     U            194.,188.,240.,254.,212.,186.,194.,161.,241.,292., CDATA  92
     U            170.,186.,232.,228.,191.,172.,178.,151.,234.,269., CDATA  93
     U            284.,217.,259.,389.,327.,262.,274.,271.,255.,379., CDATA  94
     U            698.,719.,789.,650.,742.,702.,719.,717.,814.,674., CDATA  95
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999., CDATA  96
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999., CDATA  97
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999., CDATA  98
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999./ CDATA  99
      DATA  W    /.061,.054,.052,.046,.036,.063,.091,.077,.069,.064/ CDATA 100
      DATA SIGS  /223.,202.,236.,306.,203.,109.,117.,186.,228.,292., CDATA 101
     V            444.,451.,438.,501.,360.,232.,246.,386.,435.,403., CDATA 102
     V            296.,267.,266.,419.,283.,149.,160.,275.,259.,342., CDATA 103
     V            146.,168.,195.,190.,127.,076.,079.,134.,194.,209., CDATA 104
     V            194.,204.,213.,243.,166.,099.,106.,187.,213.,225., CDATA 105
     V            223.,202.,236.,306.,203.,109.,117.,186.,228.,292., CDATA 106
     V            187.,182.,233.,246.,163.,090.,098.,133.,228.,270., CDATA 107
     V            164.,180.,225.,220.,146.,084.,089.,125.,222.,248., CDATA 108
     V            274.,206.,247.,374.,247.,126.,138.,223.,233.,338., CDATA 109
     V            655.,668.,734.,585.,457.,350.,368.,545.,719.,505., CDATA 110
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990., CDATA 111
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990., CDATA 112
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990., CDATA 113
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990./ CDATA 114
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      DATA XMUBAR/.815,.809,.871,.958,.967,.952,.922,.733,.750,.842,        CDATA  115
     W            .850,.846,.858,.938,.955,.962,.937,.830,.784,.793,        CDATA  116
     W            .830,.805,.840,.955,.968,.957,.931,.796,.712,.817,        CDATA  117
     W            .783,.846,.898,.956,.963,.945,.898,.705,.797,.852,        CDATA  118
     W            .817,.839,.875,.951,.965,.951,.913,.756,.776,.826,        CDATA  119
     W            .815,.809,.871,.958,.967,.952,.922,.733,.750,.842,        CDATA  120
     W            .799,.825,.895,.959,.965,.948,.916,.646,.788,.858,        CDATA  121
     W            .783,.838,.901,.958,.964,.947,.934,.641,.799,.859,        CDATA  122
     W            .831,.779,.853,.958,.968,.954,.929,.757,.712,.838,        CDATA  123
     W            .859,.861,.878,.918,.963,.964,.941,.850,.834,.779,        CDATA  124
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973,        CDATA  125
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973,        CDATA  126
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973,        CDATA  127
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973/        CDATA  128
C       DATA FOR CLOUD STATISTICS                                           CDATA  129
C                                                                           CDATA  130
C                                                                           CDATA  131
C                                                                           CDATA  132
C       THE DRY CLIMATE IS TAKEN FROM THE NASA DATA BASE                    CDATA  133
C       FOR REGION 11 AND IS FOR THE NOTHERN U.S. AND WESTERN EUROPE        CDATA  134
C                                                                           CDATA  135
C       THE MOIST CLOMATE IS TAKEN AS REGION 4 AND IS                       CDATA  136
C       FOR THE SOUTH PACIFIC                                               CDATA  137
C                                                                           CDATA  138
C                                                                           CDATA  139
C       1   DRY    ANNUAL    AVERAGE                                        CDATA  140
C                                                                           CDATA  141
C       2   DRY    WINTER    AVERAGE   NIGHT                                CDATA  142
C                                                                           CDATA  143
C       3   DRY    WINTER    AVERAGE   DAY                                  CDATA  144
C                                                                           CDATA  145
C       4   DRY    SUMMER    AVERAGE   NIGHT                                CDATA  146
C                                                                           CDATA  147
C       5   DRY    SUMMER    AVERAGE   DAY                                  CDATA  148
C                                                                           CDATA  149
C       6  MOIST   ANNUAL    AVERAGE                                        CDATA  150
C                                                                           CDATA  151
C       7  MOIST   WINTER    AVERAGE   NIGHT                                CDATA  152
C                                                                           CDATA  153
C       8  MOIST   WINTER    AVERAGE   DAY                                  CDATA  154
C                                                                           CDATA  155
C       9  MOIST   SUMMER    AVERAGE   NIGHT                                CDATA  156
C                                                                           CDATA  157
C       10 MOIST   SUMMER    AVERAGE   DAY                                  CDATA  158
C                                                                           CDATA  159
C       11   ARRAY FOR USER SUPPLIED DATA                                   CDATA  160
C                                                                           CDATA  161
C                                                                           CDATA  162
      DATA (CCOVER(I,1),I=1,5) /                                            CDATA  163
     X .235,.150,.070,.201,.343 /                                           CDATA  164
      DATA (CFREQ(I,1, 1),I=1,68) /                                         CDATA  165
     X .046,.046,.046,.102,.006,.005,.001,.217,.005,.005,.005,.005,.222,    CDATA  166
     X .293,.768,.212,.019,.055,.055,.055,.121,.006,.008,.001,.243,.009,    CDATA  167
     X .008,.008,.009,.164,.260,.542,.377,.081,.038,.038,.038,.169,.015,    CDATA  168
     X .010,.000,.276,.012,.010,.010,.012,.104,.266,.415,.435,.150,.010,    CDATA  169
     X .010,.010,.336,.155,.010,.030,.197,.023,.010,.010,.023,.017,.158,    CDATA  170
     X .448,.423,.128/                                                      CDATA  171
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 DATA (CCOVER(I,2),I=1,5) /                                              CDATA    172
X .306,.123,.048,.127,.396 /                                             CDATA    173
 DATA (CFREQ(I,1, 2),I=1,68) /                                           CDATA    174
X .004,.004,.004,.173,.011,.001,.001,.234,.008,.001,.001,.008,.225,      CDATA    175
X .331,.895,.105,.001,.006,.006,.006,.203,.004,.004,.001,.302,.012,      CDATA    176
X .004,.004,.012,.132,.306,.640,.335,.025,.003,.003,.003,.278,.028,      CDATA    177
X .005,.001,.299,.016,.005,.005,.016,.045,.295,.620,.331,.049,.002,      CDATA    178
X .002,.002,.407,.226,.004,.046,.154,.019,.004,.004,.019,.007,.108,      CDATA    179
X .606,.349,.045/                                                        CDATA    180
 DATA (CCOVER(I,3),I=1,5) /                                              CDATA    181
X .213,.128,.052,.179,.428 /                                             CDATA    182
 DATA (CFREQ(I,1, 3),I=1,68) /                                           CDATA    183
X .028,.028,.028,.149,.006,.001,.001,.213,.003,.001,.001,.003,.239,      CDATA    184
X .302,.798,.185,.017,.036,.036,.036,.195,.015,.001,.001,.232,.006,      CDATA    185
X .001,.001,.006,.192,.247,.564,.367,.069,.017,.017,.017,.245,.022,      CDATA    186
X .001,.001,.287,.011,.001,.001,.011,.105,.262,.463,.416,.121,.004,      CDATA    187
X .004,.004,.395,.213,.002,.035,.162,.019,.002,.002,.019,.017,.122,      CDATA    188
X .496,.399,.105/                                                        CDATA    189
 DATA (CCOVER(I,4),I=1,5) /                                              CDATA    190
X .296,.182,.084,.197,.241 /                                             CDATA    191
 DATA (CFREQ(I,1, 4),I=1,68) /                                           CDATA    192
X .035,.035,.035,.073,.002,.010,.001,.232,.006,.010,.010,.006,.220,      CDATA    193
X .327,.758,.226,.016,.032,.032,.032,.091,.002,.016,.001,.298,.009,      CDATA    194
X .016,.016,.009,.146,.302,.526,.377,.096,.022,.022,.022,.124,.012,      CDATA    195
X .019,.001,.299,.019,.019,.019,.010,.097,.307,.409,.450,.140,.008,      CDATA    196
X .008,.008,.260,.095,.027,.022,.238,.036,.027,.027,.036,.016,.191,      CDATA    197
X .370,.498,.132/                                                        CDATA    198
 DATA (CCOVER(I,5),I=1,5) /                                              CDATA    199
X .128,.164,.096,.299,.313 /                                             CDATA    200
 DATA (CFREQ(I,1, 5),I=1,68) /                                           CDATA    201
X .092,.092,.092,.059,.006,.005,.001,.196,.004,.005,.005,.004,.210,      CDATA    202
X .230,.667,.296,.038,.104,.104,.104,.077,.006,.008,.001,.177,.008,      CDATA    203
X .008,.008,.008,.178,.211,.496,.403,.101,.069,.069,.069,.124,.010,      CDATA    204
X .011,.001,.250,.007,.011,.011,.007,.126,.235,.308,.478,.214,.027,      CDATA    205
X .027,.027,.265,.074,.011,.015,.243,.021,.011,.011,.021,.029,.218,      CDATA    206
X .254,.489,.257/                                                        CDATA    207
 DATA (CCOVER(I,6),I=1,5) /                                              CDATA    208
X .181,.220,.124,.263,.212 /                                             CDATA    209
 DATA (CFREQ(I,1, 6),I=1,68) /                                           CDATA    210
X .083,.083,.083,.111,.022,.012,.001,.089,.003,.012,.012,.003,.305,      CDATA    211
X .181,.715,.270,.014,.072,.072,.072,.117,.029,.026,.001,.137,.004,      CDATA    212
X .026,.026,.004,.252,.165,.383,.520,.097,.049,.049,.049,.126,.033,      CDATA    213
X .034,.001,.187,.007,.034,.034,.007,.181,.209,.246,.517,.237,.028,      CDATA    214
X .028,.028,.211,.135,.027,.017,.173,.026,.027,.027,.026,.055,.194,      CDATA    215
X .275,.461,.265/                                                        CDATA    216
 DATA (CCOVER(I,7),I=1,5) /                                              CDATA    217
X .321,.200,.085,.184,.210 /                                             CDATA    218
 DATA (CFREQ(I,1, 7),I=1,68) /                                           CDATA    219
X .028,.028,.028,.192,.025,.002,.001,.122,.007,.002,.002,.007,.312,      CDATA    220
X .245,.866,.130,.004,.023,.023,.023,.244,.050,.004,.001,.198,.006,      CDATA    221
X .004,.004,.006,.190,.224,.657,.302,.041,.016,.016,.016,.253,.060,      CDATA    222
X .004,.001,.241,.010,.004,.004,.010,.085,.283,.488,.420,.092,.007,      CDATA    223
X .007,.007,.323,.230,.011,.030,.153,.032,.011,.011,.032,.011,.135,      CDATA    224
X .428,.459,.114/                                                        CDATA    225
 DATA (CCOVER(I,8),I=1,5) /                                              CDATA    226
X .150,.237,.124,.251,.238 /                                             CDATA    227
 DATA (CFREQ(I,1, 8),I=1,68) /                                           CDATA    228
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      X .094,.094,.094,.128,.027,.003,.001,.104,.003,.003,.003,.003,.282, CDATA     229
      X .161,.737,.249,.014,.078,.078,.078,.151,.034,.004,.001,.176,.005, CDATA     230
      X .004,.004,.005,.197,.187,.436,.474,.091,.051,.051,.051,.187,.041, CDATA     231
      X .007,.001,.225,.008,.007,.007,.008,.135,.220,.289,.506,.206,.020, CDATA     232
      X .020,.020,.285,.197,.007,.020,.156,.031,.007,.007,.031,.025,.171, CDATA     233
      X .347,.456,.197/                                                   CDATA     234
       DATA (CCOVER(I,9),I=1,5) /                                         CDATA     235
      X .197,.232,.118,.256,.197 /                                        CDATA     236
       DATA (CFREQ(I,1, 9),I=1,68) /                                      CDATA     237
      X .055,.055,.055,.110,.022,.017,.001,.074,.003,.017,.017,.003,.332, CDATA     238
      X .240,.721,.269,.010,.050,.050,.050,.145,.029,.025,.001,.142,.005, CDATA     239
      X .025,.025,.005,.248,.200,.355,.533,.112,.043,.043,.043,.112,.023, CDATA     240
      X .039,.002,.182,.008,.039,.039,.008,.202,.218,.233,.522,.245,.031, CDATA     241
      X .031,.031,.154,.065,.041,.011,.196,.025,.041,.041,.025,.089,.221, CDATA     242
      X .190,.456,.354/                                                   CDATA     243
       DATA (CCOVER(I,10),I=1,5) /                                        CDATA     244
      X .057,.212,.167,.360,.204 /                                        CDATA     245
       DATA (CFREQ(I,1,10),I=1,68) /                                      CDATA     246
      X .136,.136,.136,.038,.016,.025,.001,.067,.000,.025,.025,.000,.297, CDATA     247
      X .098,.546,.424,.030,.100,.100,.100,.031,.019,.048,.001,.087,.001, CDATA     248
      X .048,.048,.001,.311,.106,.227,.654,.119,.065,.065,.065,.052,.025, CDATA     249
      X .058,.000,.149,.004,.058,.058,.004,.229,.169,.105,.569,.326,.046, CDATA     250
      X .046,.046,.114,.073,.044,.010,.181,.018,.044,.044,.018,.084,.232, CDATA     251
      X .120,.472,.408/                                                   CDATA     252
       DATA (CCOVER(I,11),I=1,5) /  5*0. /                                CDATA     253
       DATA (CFREQ(I,1,11),I=1,68) /  68*0. /                             CDATA     254
       END                                                                CDATA     255
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```
      FUNCTION CFLOSF(ICC,ANGLE)
      DIMENSION CFLOST(11,10),ANGT(10)
C
COMMENT  THE ITH COL IS THE CLOUD COVERAGE CAT IN 10THS
C          THE ROW IS ELEVATION ANGLE IN DEGREES
C
CCC
CLJ   FUNCTION CFLOSF COMPUTES THE PROBABILITY OF A CLOUD-FREE
CLJ   LINE-OF-SIGHT (CFLOS) AS A FUNCTION OF THE CLOUD-COVERAGE AND
CLJ   ZENITH ANGLE OF THE LOS FROM THE GROUND.
CCC
CLJ   INPUT PARAMETERS
CLJ      ARGUMENT LIST
CLJ          ICC-1 = CLOUD COVERAGE IN TENTHS, 0(1)10
CLJ          ANGLE = ZENITH ANGLE OF LOS FROM EARTH'S SURFACE, DEGREES
CLJ   OUTPUT PARAMETER
CLJ      FUNCTION
CLJ         CFLOSF = PROBABILITY OF CFLOS FOR GIVEN INPUT PARAMETERS
CLJ   DEFINITION OF DATA
CLJ               ANGT(IA) = ZENITH ANGLE OF ((IA-1)*10)-DEGREES
CLJ         CFLOST(ICC,IA) = PROBABILITY OF CFLOS FOR CLOUD-COVERAGE
CLJ                          OF (ICC-1)-TENTHS AND ZENITH ANGLE OF
CLJ                          ((IA-1)*10)-DEGREES
CLJ               IA  = 1,10  ROW
CLJ               ICC = 1,11  COLUMN
CCC
CLJ   THE TABULAR DATA (EXCEPT FOR THE BOTTOM ROW) ARE FROM LUND AND
CLJ   SHANKLIN (LS-73, TABLE 3), A CASE FOR WHICH ALL CLOUD TYPES ARE
CLJ   INCLUDED IN THE DATA SAMPLE.  WE OBTAINED THE BOTTOM-ROW VALUES
CLJ   AT 90-DEGREE ZENITH ANGLE BY EXTRAPOLATION.
CCC
      DATA ANGT /0.,10.,20.,30.,40.,50.,60.,70.,80.,90. /
      DATA CFLOST/
     X        .99, .97, .92, .87, .81, .77, .70, .62, .48, .31, .08
     X      , .99, .97, .92, .87, .81, .77, .69, .61, .47, .31, .08
     X      , .99, .97, .91, .86, .80, .76, .68, .61, .47, .30, .08
     X      , .99, .96, .90, .85, .80, .75, .66, .60, .46, .29, .08
     X      , .99, .96, .90, .85, .78, .73, .64, .58, .45, .29, .08
     X      , .99, .95, .88, .83, .76, .71, .62, .55, .42, .27, .07
     X      , .98, .93, .86, .80, .73, .66, .57, .50, .38, .24, .06
     X      , .98, .90, .83, .75, .67, .59, .50, .42, .33, .21, .05
     X      , .97, .86, .76, .65, .55, .47, .39, .32, .24, .16, .03
     X      , .94, .79, .66, .52, .40, .32, .27, .21, .14, .08, .00
     X      /
CLJ
      IF( (ANGLE.LT.0.0) .OR. (ANGLE.GT.90.) )  WRITE(6,101)  ANGLE
  101 FORMAT (32H0  *** WARNING FROM CFLOSF ***  ,5X,8H ANGLE =,F8.3,
     $ 56H   AND IS NOT WITHIN THE TABULAR VALUES OF ZENITH ANGLE.)
CLJ
      DO 10 I = 2,10
      IA = I - 1
      IF(ANGLE .LT. ANGT(I)) GO TO 20
   10 CONTINUE
      IA = 9
   20 CONTINUE
      CFLOSF = CFLOST(ICC,IA) + (CFLOST(ICC,IA+1) - CFLOST(ICC,IA))
     X    *( ANGLE - ANGT(IA)) / (ANGT(IA+1) - ANGT(IA))
      RETURN
      END
```

```
      FUNCTION CLDBDR(CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD)                 CLDBDR
C                                                                      CLDBDR
C        ENTRIES IN THE FOLLOWING TABLES ARE BI-DIRECTIONAL            CLDBDR
C        REFLECTANCES FOR A STRATOCUMULUS CLOUD AT THE ANGLES AND      CLDBDR
C        WAVELENGTH IN THE ASSOCIATED TABLES                           CLDBDR
C                                                                      CLDBDR
CCC                                                                    CLDBDR
CLJ   FUNCTION CLDBDR PROVIDES THE BIDIRECTIONAL REFLECTANCE (1/SR) OF CLDBDR
CLJ   A PLANE, SEMI-INFINITE STRATOCUMULUS (KCLOUD=4) CLOUD FOR A      CLDBDR
CLJ   PHOTON OF WAVELENGTH ALAM INCIDENT AT ZENITH ANGLE THIN=         CLDBDR
CLJ   ACOS(CTHIN) AND REFLECTED AT ZENITH ANGLE THOUT=ACOS(CTHOUT) AND CLDBDR
CLJ   AZIMUTH ANGLE PHIOUT=ACOS(CPHIOUT).                              CLDBDR
CCC                                                                    CLDBDR
CLJ   INPUT PARAMETERS                                                 CLDBDR
CLJ      ARGUMENT LIST                                                 CLDBDR
CLJ           CTHIN = COSINE OF ZENITH ANGLE OF INCIDENT RAY           CLDBDR
CLJ          CTHOUT = COSINE OF ZENITH ANGLE OF EXIT RAY               CLDBDR
CLJ          CPHOUT = COSINE OF AZIMUTHAL ANGLE OF EXIT RAY            CLDBDR
CLJ            ALAM = WAVELENGTH, MICRONS                              CLDBDR
CLJ          KCLOUD = INDEX OF CLOUD TYPE (1 TO 14) NOT CURRENTLY      CLDBDR
CLJ                   ( 2/22/78) USED.  DATA FOR ONLY ONE CLOUD TYPE   CLDBDR
CLJ                   (STRATOCUMULUS, FOR WHICH KCLOUD=4) ARE INCLUDED. CLDBDR
CLJ   OUTPUT PARAMETER                                                 CLDBDR
CLJ      FUNCTION                                                      CLDBDR
CLJ          CLDBDR = BIDIRECTIONAL REFLECTANCE,  1/SR                 CLDBDR
CLJ   DEFINITION OF DATA                                               CLDBDR
CLJ      RFL'N'(J,K,I) = BIDIRECTIONAL REFLECTANCE OF A PLANE,         CLDBDR
CLJ                      SEMI-INFINITE STRATOCUMULUS (KCLOUD=4) CLOUD  CLDBDR
CLJ                      FOR A PHOTON OF WAVELENGTH ALAMT(N) INCIDENT  CLDBDR
CLJ                      AT ZENITH ANGLE THIN(I) = ACOS(TCTIN(I)) AND  CLDBDR
CLJ                      REFLECTED AT ZENITH ANGLE THOUT(J)=           CLDBDR
CLJ                      ACOS( TCTHOUT(J) ) AND                        CLDBDR
CLJ                      AZIMUTH ANGLE PHOUT(K) = ACOS(TCPHOUT(K)).    CLDBDR
CCC                                                                    CLDBDR
CLJ                WHERE  N=1,10,  J=1,5,  K=1,9, AND I=1,4            CLDBDR
CCC                                                                    CLDBDR
CLJ                      THE DATA WERE GENERATED BY THE SAI/PALO ALTO  CLDBDR
CLJ                      MONTE CARLO IR CODE FOR INCIDENT ZENITH ANGLES CLDBDR
CLJ                      OF 0,30,60, AND 80 DEGREES (FOR WHICH COSINES CLDBDR
CLJ                      1.0,0.866,0.5, AND 0.1736).                   CLDBDR
CLJ                      TO GENERATE INCIDENT ZENITH-ANGLE             CLDBDR
CLJ                      BIN-BOUNDARIES FOR CURRENT APPLICATIONS, WE   CLDBDR
CLJ                      SELECT THE MIDPOINT VALUES OF THE COSINES     CLDBDR
CLJ                      USED IN THE MONTE CARLO CALCULATION, RESULTING CLDBDR
CLJ                      IN ANGLES OF 0.0, 21.09, 46.92, 70.32, AND    CLDBDR
CLJ                      90.0 DEGREES.                                 CLDBDR
CLJ                      THE COSINES OF THE EXIT ZENITH-ANGLE          CLDBDR
CLJ                      BIN-BOUNDARIES ARE 1.0(0.2)0.0 OR ZENITH      CLDBDR
CLJ                      ANGLES OF 0.0, 36.87, 53.13, 66.42, 78.46,    CLDBDR
CLJ                      AND 90.0 DEGREES.  THE EXIT                   CLDBDR
CLJ                      AZIMUTH-ANGLE BIN-BOUNDARIES ARE 0(20)180     CLDBDR
CLJ                      DEGREES.  THE ORIGINALLY-RECORDED MONTE CARLO CLDBDR
CLJ                      RESULTS FOR THE NUMBER OF PHOTONS PER BIN WERE CLDBDR
CLJ                      DIVIDED BY THE SOLID ANGLE OF THE BIN AND THE CLDBDR
CLJ                      COSINE OF THE EXIT ZENITH ANGLE.              CLDBDR
CCC                                                                    CLDBDR
      DIMENSION TCPHOUT(9),TCTHOUT(5),TCTHIN(4)                        CLDBDR
```

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            DIMENSION RFL1( 5,9,4),RFL2( 5,9,4),RFL3( 5,9,4),RFL4( 5,9,4)       CLDBDR    59
            DIMENSION RFL5( 5,9,4),RFL6( 5,9,4),RFL7( 5,9,4),RFL8( 5,9,4)       CLDBDR    60
            DIMENSION RFL9( 5,9,4),RFL10(5,9,4)                                 CLDBDR    61
            COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),             CDDATA     2
           1 XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)              CDDATA     3
            DATA TCTHIN / 0.933,0.683,0.337, 0.  /                             CLDBDR    63
            DATA TCPHOUT / -0.9397,-0.766,-0.5,-0.1736,0.1736,0.5,             CLDBDR    64
           X   .7660,.9397,1.0 /                                               CLDBDR    65
            DATA TCTHOUT / 0.8,0.6,0.4,0.2,0.0 /                               CLDBDR    66
      CLJ                                                                      CLDBDR    67
      CLJ                                                                      CLDBDR    68
      CLJ                 EXIT ZENITH-ANGLE BINS AND THEIR COSINES             CLDBDR    69
      CLJ   ---------------------------------------------------------------    CLDBDR    70
      CLJ         1        2        3        4        5     EXIT ZENITH BIN NO. CLDBDR 71
      CLJ   0.00   36.87    53.13    66.42    78.46    90.00  EXIT ZENITH ANGLE  CLDBDR  72
      CLJ   1.00    0.80     0.60     0.40     0.20     0.00  EXIT ZENITH COSINE CLDBDR  73
      CLJ                                                                      CLDBDR    74
      CLJ        AZIMUTH ANGLE BINS                                            CLDBDR    75
      CLJ        ------------------                                            CLDBDR    76
      CLJ              160-180                                                 CLDBDR    77
      CLJ              140-160                                                 CLDBDR    78
      CLJ              120-140                                                 CLDBDR    79
      CLJ              100-120                                                 CLDBDR    80
      CLJ               80-100                                                 CLDBDR    81
      CLJ               60- 80                                                 CLDBDR    82
      CLJ               40- 60                                                 CLDBDR    83
      CLJ               20- 40                                                 CLDBDR    84
      CLJ                0- 20                                                 CLDBDR    85
      CLJ                                                                      CLDBDR    86
      CLJ                                                                      CLDBDR    87
      C     DATA KPN,XLAM,WZERO/  420, 2.00, 1.00000E+00/                      CLDBDR    88
            DATA(RFL1(I,1,1),I=1,45)                                           CLDBDR    89
           X / 8.0183E-02 , 7.7606E-02 , 7.0873E-02 , 5.8618E-02 , 5.0204E-02, CLDBDR    90
           X   7.3561E-02 , 7.4827E-02 , 7.0089E-02 , 5.6753E-02 , 4.3310E-02, CLDBDR    91
           X   8.9787E-02 , 8.0147E-02 , 6.8212E-02 , 5.3634E-02 , 4.5461E-02, CLDBDR    92
           X   7.8864E-02 , 7.5420E-02 , 7.0664E-02 , 6.4422E-02 , 7.0314E-02, CLDBDR    93
           X   8.4760E-02 , 8.2725E-02 , 7.4955E-02 , 5.9629E-02 , 4.6133E-02, CLDBDR    94
           X   7.7259E-02 , 7.8899E-02 , 8.3598E-02 , 9.6162E-02 , 1.6524E-01, CLDBDR    95
           X   8.5633E-02 , 9.9457E-02 , 1.0188E-01 , 8.3087E-02 , 5.4070E-02, CLDBDR    96
           X   8.8204E-02 , 7.9470E-02 , 7.1003E-02 , 6.3169E-02 , 7.0499E-02, CLDBDR    97
           X   7.7388E-02 , 8.5621E-02 , 8.6023E-02 , 7.2751E-02 , 5.4949E-02/ CLDBDR    98
      C     DATA KPN,XLAM,WZERO/  420, 2.00, 8.66000E-01/                      CLDBDR    99
            DATA(RFL1(I,1,2),I=1,45)                                           CLDBDR   100
           X / 1.0886E-01 , 1.1597E-01 , 1.1345E-01 , 9.5432E-02 , 7.4834E-02, CLDBDR   101
           X   1.1423E-01 , 1.2180E-01 , 1.2054E-01 , 1.0468E-01 , 8.8306E-02, CLDBDR   102
           X   1.1755E-01 , 1.1679E-01 , 1.0687E-01 , 8.4575E-02 , 6.3128E-02, CLDBDR   103
           X   1.0420E-01 , 1.1626E-01 , 1.1860E-01 , 1.0319E-01 , 8.2334E-02, CLDBDR   104
           X   1.0768E-01 , 1.1415E-01 , 1.1220E-01 , 9.6594E-02 , 8.0478E-02, CLDBDR   105
           X   1.0843E-01 , 1.0430E-01 , 9.6947E-02 , 8.5427E-02 , 8.5490E-02, CLDBDR   106
           X   1.0716E-01 , 1.0204E-01 , 9.7342E-02 , 9.4312E-02 , 1.1929E-01, CLDBDR   107
           X   9.5653E-02 , 1.0515E-01 , 1.1120E-01 , 1.1054E-01 , 1.2266E-01, CLDBDR   108
           X   9.7681E-02 , 1.0920E-01 , 1.1618E-01 , 1.1379E-01 , 1.1930E-01/ CLDBDR   109
      C     DATA KPN,XLAM,WZERO/  420, 2.00, 5.00000E-01/                      CLDBDR   110
            DATA(RFL1(I,1,3),I=1,45)                                           CLDBDR   111
           X / 9.8035E-02 , 1.3408E-01 , 1.6575E-01 , 1.7096E-01 , 1.5468E-01, CLDBDR   112
           X   1.0831E-01 , 1.3218E-01 , 1.4879E-01 , 1.4523E-01 , 1.3444E-01, CLDBDR   113
           X   1.0799E-01 , 1.2610E-01 , 1.3620E-01 , 1.2823E-01 , 1.1572E-01, CLDBDR   114
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      X    9.6639E-02 , 1.1830E-01 , 1.3360E-01 , 1.3091E-01 , 1.2179E-01, CLDBDR   115
      X    1.0559E-01 , 1.2558E-01 , 1.3851E-01 , 1.3389E-01 , 1.2538E-01, CLDBDR   116
      X    9.6630E-02 , 1.2188E-01 , 1.4431E-01 , 1.5323E-01 , 1.6513E-01, CLDBDR   117
      X    1.0342E-01 , 1.4198E-01 , 1.8309E-01 , 2.1201E-01 , 2.4983E-01, CLDBDR   118
      X    1.0525E-01 , 1.5226E-01 , 2.1115E-01 , 2.7332E-01 , 3.8946E-01, CLDBDR   119
      X    9.7656E-02 , 1.5791E-01 , 2.4487E-01 , 3.5475E-01 , 5.6659E-01/ CLDBDR   120
C      DATA KPN,XLAM,WZERO/  420, 2.00, 1.73600E-01/                       CLDBDR   121
       DATA(RFL1(I,1,4),I=1,45)                                            CLDBDR   122
      X / 8.8371E-02 , 1.1898E-01 , 1.6013E-01 , 2.1793E-01 , 3.8377E-01, CLDBDR   123
      X    7.6074E-02 , 1.1333E-01 , 1.5625E-01 , 1.8800E-01 , 2.1734E-01, CLDBDR   124
      X    8.5090E-02 , 1.1552E-01 , 1.4847E-01 , 1.7389E-01 , 2.1357E-01, CLDBDR   125
      X    7.3286E-02 , 9.3107E-02 , 1.1341E-01 , 1.2897E-01 , 1.6150E-01, CLDBDR   126
      X    7.4517E-02 , 1.0633E-01 , 1.4107E-01 , 1.6475E-01 , 1.8816E-01, CLDBDR   127
      X    7.8939E-02 , 1.2188E-01 , 1.7802E-01 , 2.3662E-01 , 3.2885E-01, CLDBDR   128
      X    8.9686E-02 , 1.5592E-01 , 2.5798E-01 , 3.9300E-01 , 6.4094E-01, CLDBDR   129
      X    9.3658E-02 , 1.9538E-01 , 3.8712E-01 , 7.0346E-01 , 1.3578E+00, CLDBDR   130
      X    1.0526E-01 , 2.3634E-01 , 5.1294E-01 , 1.0559E+00 , 2.4709E+00/ CLDBDR   131
C      DATA KPN,XLAM,WZERO/  425, 2.50, 1.00000E+00/                       CLDBDR   132
       DATA(RFL2(I,1,1),I=1,45)                                            CLDBDR   133
      X / 5.3727E-02 , 6.1630E-02 , 6.4746E-02 , 5.8192E-02 , 4.8267E-02, CLDBDR   134
      X    7.0241E-02 , 7.9019E-02 , 8.0958E-02 , 7.0207E-02 , 5.4988E-02, CLDBDR   135
      X    7.4191E-02 , 9.9237E-02 , 1.1306E-01 , 9.5938E-02 , 5.6776E-02, CLDBDR   136
      X    1.0199E-01 , 1.0267E-01 , 1.1479E-01 , 1.5868E-01 , 4.2624E-01, CLDBDR   137
      X    8.6435E-02 , 7.1816E-02 , 7.1367E-02 , 1.0100E-01 , 3.6964E-01, CLDBDR   138
      X    6.6220E-02 , 6.7968E-02 , 6.5901E-02 , 5.7996E-02 , 5.3084E-02, CLDBDR   139
      X    7.9669E-02 , 8.3811E-02 , 8.1954E-02 , 7.0528E-02 , 5.9312E-02, CLDBDR   140
      X    8.0562E-02 , 9.8494E-02 , 1.0504E-01 , 8.7339E-02 , 5.5538E-02, CLDBDR   141
      X    8.4083E-02 , 8.4396E-02 , 7.7552E-02 , 6.0925E-02 , 4.4109E-02/ CLDBDR   142
C      DATA KPN,XLAM,WZERO/  425, 2.50, 8.66000E-01/                     , CLDBDR   143
       DATA(RFL2(I,1,2),I=1,45)                                            CLDBDR   144
      X / 8.2263E-02 , 8.7706E-02 , 8.6131E-02 , 7.3159E-02 , 5.8628E-02, CLDBDR   145
      X    8.8715E-02 , 9.2875E-02 , 9.0141E-02 , 7.6615E-02 , 6.3000E-02, CLDBDR   146
      X    7.8392E-02 , 8.3588E-02 , 8.4315E-02 , 7.8537E-02 , 7.8790E-02, CLDBDR   147
      X    7.9467E-02 , 8.7295E-02 , 8.8160E-02 , 7.6728E-02 , 6.2545E-02, CLDBDR   148
      X    7.9952E-02 , 9.2947E-02 , 9.7663E-02 , 8.5611E-02 , 6.5820E-02, CLDBDR   149
      X    8.6310E-02 , 9.7049E-02 , 1.0191E-01 , 9.5043E-02 , 8.8214E-02, CLDBDR   150
      X    8.6138E-02 , 1.0412E-01 , 1.1298E-01 , 1.0095E-01 , 7.7064E-02, CLDBDR   151
      X    1.0002E-01 , 1.0984E-01 , 1.1135E-01 , 9.8033E-02 , 8.2113E-02, CLDBDR   152
      X    1.3301E-01 , 1.2562E-01 , 1.1543E-01 , 1.0182E-01 , 1.0465E-01/ CLDBDR   153
C      DATA KPN,XLAM,WZERO/  425, 2.50, 5.00000E-01/                     , CLDBDR   154
       DATA(RFL2(I,1,3),I=1,45)                                            CLDBDR   155
      X / 7.7234E-02 , 9.7073E-02 , 1.0976E-01 , 1.0261E-01 , 8.2614E-02, CLDBDR   156
      X    1.0662E-01 , 1.1630E-01 , 1.1863E-01 , 1.0770E-01 , 9.7784E-02, CLDBDR   157
      X    9.9455E-02 , 1.0835E-01 , 1.1120E-01 , 1.0304E-01 , 9.8264E-02, CLDBDR   158
      X    8.7188E-02 , 1.0490E-01 , 1.1519E-01 , 1.0750E-01 , 9.1368E-02, CLDBDR   159
      X    1.0139E-01 , 1.2075E-01 , 1.3098E-01 , 1.2027E-01 , 9.9773E-02, CLDBDR   160
      X    9.5764E-02 , 1.1661E-01 , 1.3587E-01 , 1.4730E-01 , 1.7458E-01, CLDBDR   161
      X    9.5993E-02 , 1.3746E-01 , 1.8236E-01 , 2.1158E-01 , 2.3687E-01, CLDBDR   162
      X    1.0420E-01 , 1.5515E-01 , 2.2161E-01 , 2.9586E-01 , 4.3593E-01, CLDBDR   163
      X    9.7049E-02 , 1.6485E-01 , 2.6470E-01 , 3.8630E-01 , 5.8798E-01/ CLDBDR   164
C      DATA KPN,XLAM,WZERO/  425, 2.50, 1.73600E-01/                       CLDBDR   165
       DATA(RFL2(I,1,4),I=1,45)                                            CLDBDR   166
      X / 6.6116E-02 , 8.1417E-02 , 9.7471E-02 , 1.1189E-01 , 1.4927E-01, CLDBDR   167
      X    6.5009E-02 , 8.2617E-02 , 9.8767E-02 , 1.0631E-01 , 1.1712E-01, CLDBDR   168
      X    6.7225E-02 , 8.3578E-02 , 9.9654E-02 , 1.1100E-01 , 1.3633E-01, CLDBDR   169
      X    7.4215E-02 , 9.1721E-02 , 1.0756E-01 , 1.1547E-01 , 1.3118E-01, CLDBDR   170
      X    8.2809E-02 , 1.0224E-01 , 1.2230E-01 , 1.3935E-01 , 1.8206E-01, CLDBDR   171
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     X   8.1586E-02 , 1.1835E-01 , 1.6309E-01 , 2.0617E-01 , 2.7698E-01, CLDBDR    172
     X   8.7018E-02 , 1.4830E-01 , 2.4356E-01 , 3.7714E-01 , 6.5601E-01, CLDBDR    173
     X   9.0367E-02 , 1.9329E-01 , 3.9618E-01 , 7.5734E-01 , 1.5910E+00, CLDBDR    174
     X   9.6798E-02 , 2.3813E-01 , 5.7311E-01 , 1.3384E+00 , 3.7215E+00/ CLDBDR    175
C      DATA KPN,XLAM,WZERO/  425, 2.55, 1.00000E+00/                      CLDBDR    176
       DATA(RFL3(I,1,1),I=1,45)                                           CLDBDR    177
     X / 5.3080E-02 , 5.6633E-02 , 5.5481E-02 , 4.6728E-02 , 3.6680E-02, CLDBDR    178
     X   5.1942E-02 , 5.5347E-02 , 5.3626E-02 , 4.3847E-02 , 3.2184E-02, CLDBDP    179
     X   4.2704E-02 , 4.5964E-02 , 4.6054E-02 , 4.0727E-02 , 3.5398E-02, CLDBDR    180
     X   4.1380E-02 , 4.7951E-02 , 5.1247E-02 , 4.7488E-02 , 4.1724E-02, CLDBDR    181
     X   4.9008E-02 , 5.9867E-02 , 6.5271E-02 , 5.7953E-02 , 4.2984E-02, CLDBDR    182
     X   4.6718E-02 , 5.8984E-02 , 6.4441E-02 , 5.4046E-02 , 3.3602E-02, CLDBDR    183
     X   5.1907E-02 , 5.7727E-02 , 5.8520E-02 , 5.0300E-02 , 3.9182E-02, CLDBDR    184
     X   5.3280E-02 , 5.3948E-02 , 5.1621E-02 , 4.4863E-02 , 4.0610E-02, CLDBDR    185
     X   6.6145E-02 , 6.5463E-02 , 5.9458E-02 , 4.6381E-02 , 3.3653E-02/ CLDBDR    186
C      DATA KPN,XLAM,WZERO/  425, 2.55, 8.66000E-01/                      CLDBDR    187
       DATA(RFL3(I,1,2),I=1,45)                                           CLDBDR    188
     X / 5.3116E-02 , 6.0725E-02 , 6.2799E-02 , 5.4263E-02 , 4.1250E-02, CLDBDR    189
     X   6.2341E-02 , 6.8552E-02 , 6.8937E-02 , 5.9144E-02 , 4.6567E-02, CLDBDR    190
     X   6.2054E-02 , 6.9266E-02 , 7.0409E-02 , 6.0571E-02 , 4.7049E-02, CLDBDR    191
     X   5.5733E-02 , 6.6122E-02 , 7.0300E-02 , 6.1344E-02 , 4.5423E-02, CLDBDR    192
     X   7.4886E-02 , 8.1302E-02 , 8.1426E-02 , 7.0738E-02 , 5.8321E-02, CLDBDR    193
     X   7.5930E-02 , 8.6479E-02 , 8.8884E-02 , 7.5986E-02 , 5.6630E-02, CLDBDR    194
     X   7.1444E-02 , 8.3095E-02 , 8.8617E-02 , 8.1038E-02 , 6.8708E-02, CLDBDR    195
     X   7.9813E-02 , 8.7759E-02 , 9.1947E-02 , 8.8896E-02 , 9.2430E-02, CLDBDR    196
     X   6.9786E-02 , 8.7299E-02 , 9.9263E-02 , 9.5180E-02 , 8.1806E-02/ CLDBDR    197
C      DATA KPN,XLAM,WZERO/  425, 2.55, 5.00000E-01/                      CLDBDR    198
       DATA(RFL3(I,1,3),I=1,45)                                           CLDBDR    199
     X / 5.9895E-02 , 7.1368E-02 , 7.8590E-02 , 7.5331E-02 , 6.9010E-02, CLDBDR    200
     X   6.7293E-02 , 7.4836E-02 , 7.8167E-02 , 7.3294E-02 , 6.9907E-02, CLDBDR    201
     X   6.5089E-02 , 7.7425E-02 , 8.5385E-02 , 8.2462E-02 , 7.7048E-02, CLDBDR    202
     X   6.7841E-02 , 8.1656E-02 , 9.0735E-02 , 8.7587E-02 , 8.0476E-02, CLDBDR    203
     X   7.9548E-02 , 9.9686E-02 , 1.1445E-01 , 1.1251E-01 , 1.0224E-01, CLDBDR    204
     X   7.6502E-02 , 1.0476E-01 , 1.2959E-01 , 1.3360E-01 , 1.2054E-01, CLDBDR    205
     X   8.1443E-02 , 1.2205E-01 , 1.6570E-01 , 1.8850E-01 , 1.8977E-01, CLDBDR    206
     X   8.3993E-02 , 1.4186E-01 , 2.2091E-01 , 2.9812E-01 , 3.8109E-01, CLDBDR    207
     X   8.7714E-02 , 1.5825E-01 , 2.6484E-01 , 3.8856E-01 , 5.5270E-01/ CLDBDR    208
C      DATA KPN,XLAM,WZERO/  425, 2.55, 1.73600E-01/                      CLDBDR    209
       DATA(RFL3(I,1,4),I=1,45)                                           CLDBDR    210
     X / 5.0543E-02 , 5.7898E-02 , 6.4396E-02 , 6.8505E-02 , 8.4270E-02, CLDBDR    211
     X   5.6872E-02 , 6.6530E-02 , 7.4678E-02 , 7.8390E-02 , 9.0911E-02, CLDBDR    212
     X   5.5087E-02 , 6.7625E-02 , 7.8474E-02 , 8.2760E-02 , 9.1016E-02, CLDBDR    213
     X   5.5371E-02 , 7.2550E-02 , 8.8824E-02 , 9.6674E-02 , 1.0493E-01, CLDBDR    214
     X   5.7212E-02 , 8.6306E-02 , 1.1826E-01 , 1.3645E-01 , 1.4075E-01, CLDBDR    215
     X   6.6218E-02 , 9.9905E-02 , 1.4261E-01 , 1.8530E-01 , 2.5191E-01, CLDBDR    216
     X   7.8890E-02 , 1.3997E-01 , 2.3525E-01 , 3.6084E-01 , 5.8200E-01, CLDBDR    217
     X   9.1536E-02 , 1.9111E-01 , 3.8695E-01 , 7.4777E-01 , 1.6637E+00, CLDBDR    218
     X   8.3974E-02 , 2.2028E-01 , 5.7006E-01 , 1.4547E+00 , 4.5656E+00/ CLDBDR    219
C      DATA KPN,XLAM,WZERO/  426, 2.65, 1.00000E+00/                      CLDBDR    220
       DATA(RFL4(I,1,1),I=1,45)                                           CLDBDR    221
     X / 6.3315E-02 , 4.0561E-02 , 2.6888E-02 , 1.9253E-02 , 2.0385E-02, CLDBDR    222
     X   1.5078E-02 , 1.8480E-02 , 2.0599E-02 , 1.9386E-02 , 1.6392E-02, CLDBDR    223
     X   2.5759E-02 , 2.5570E-02 , 2.3832E-02 , 1.9924E-02 , 1.6919E-02, CLDBDR    224
     X   1.2604E-02 , 1.8186E-02 , 2.3053E-02 , 2.3090E-02 , 1.8173E-02, CLDBDR    225
     X   1.5646E-02 , 1.8703E-02 , 2.0181E-02 , 1.8123E-02 , 1.4203E-02, CLDBDP    226
     X   1.5339E-02 , 1.8986E-02 , 2.0746E-02 , 1.8080E-02 , 1.2618E-02, CLDBDR    227
     X   1.2337E-02 , 1.6194E-02 , 1.9009E-02 , 1.8237E-02 , 1.4723E-02, CLDBDR    228
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     X   1.5218E-02 , 1.8083E-02 , 1.9773E-02 , 1.8667E-02 , 1.6569E-02, CLDBDR    229
     X   1.6500E-02 , 1.8949E-02 , 1.9788E-02 , 1.7442E-02 , 1.3805E-02/ CLDBDR    230
C     DATA KPN,XLAM,WZERO/  426,  2.65, 8.66000E-01/                      CLDBDR    231
      DATA(RFL4(I,1,2),I=1,45)                                            CLDBDR    232
     X / 1.9286E-02 , 1.9867E-02 , 2.1841E-02 , 2.7512E-02 , 5.7734E-02, CLDBDR    233
     X   2.0659E-02 , 2.1434E-02 , 2.1508E-02 , 2.0491E-02 , 2.2240E-02, CLDBDR    234
     X   2.9040E-02 , 2.7928E-02 , 2.5564E-02 , 2.1548E-02 , 1.9449E-02, CLDBDR    235
     X   2.3239E-02 , 2.8073E-02 , 3.0224E-02 , 2.6428E-02 , 1.9196E-02, CLDBDR    236
     X   4.4608E-02 , 4.2016E-02 , 3.6877E-02 , 2.8621E-02 , 2.1917E-02, CLDBDR    237
     X   6.3218E-02 , 5.2735E-02 , 4.3015E-02 , 3.4017E-02 , 3.1970E-02, CLDBDR    238
     X   3.9126E-02 , 4.9393E-02 , 5.5157E-02 , 4.9315E-02 , 3.5587E-02, CLDBDR    239
     X   5.4105E-02 , 5.3592E-02 , 5.1163E-02 , 4.6063E-02 , 4.6607E-02, CLDBDR    240
     X   2.7891E-02 , 4.1406E-02 , 5.5037E-02 , 5.9943E-02 , 5.5217E-02/ CLDBDR    241
C     DATA KPN,XLAM,WZERO/  426,  2.65, 5.00000E-01/                      CLDBDR    242
      DATA(RFL4(I,1,3),I=1,45)                                            CLDBDR    243
     X / 2.0567E-02 , 2.1964E-02 , 2.2215E-02 , 2.0493E-02 , 1.9857E-02, CLDBDR    244
     X   2.3287E-02 , 2.5669E-02 , 2.5258E-02 , 2.0247E-02 , 1.3567E-02, CLDBDR    245
     X   2.4385E-02 , 2.8598E-02 , 3.0810E-02 , 2.8565E-02 , 2.4735E-02, CLDBDR    246
     X   2.8298E-02 , 3.4536E-02 , 3.9053E-02 , 3.8628E-02 , 3.6879E-02, CLDBDR    247
     X   3.5004E-02 , 4.6211E-02 , 5.5837E-02 , 5.7652E-02 , 5.4803E-02, CLDBDR    248
     X   3.7861E-02 , 5.9642E-02 , 8.2341E-02 , 8.9417E-02 , 7.5610E-02, CLDBDR    249
     X   3.9138E-02 , 7.3356E-02 , 1.1932E-01 , 1.4985E-01 , 1.4111E-01, CLDBDR    250
     X   4.3935E-02 , 9.2955E-02 , 1.7236E-01 , 2.5140E-01 , 2.8556E-01, CLDBDR    251
     X   4.9392E-02 , 1.0765E-01 , 2.1186E-01 , 3.4716E-01 , 4.9702E-01/ CLDBDR    252
C     DATA KPN,XLAM,WZERO/  426,  2.65, 1.73600E-01/                      CLDBDR    253
      DATA(RFL4(I,1,4),I=1,45)                                            CLDBDR    254
     X / 1.5844E-02 , 1.8345E-02 , 1.9749E-02 , 1.8721E-02 , 1.7363E-02, CLDBDR    255
     X   1.9145E-02 , 2.1033E-02 , 2.1560E-02 , 1.9591E-02 , 1.7653E-02, CLDBDR    256
     X   2.2144E-02 , 2.3309E-02 , 2.4826E-02 , 2.7362E-02 , 4.0892E-02, CLDBDR    257
     X   2.4163E-02 , 2.9487E-02 , 3.4828E-02 , 3.9111E-02 , 5.0175E-02, CLDBDR    258
     X   2.6139E-02 , 4.1230E-02 , 5.7635E-02 , 6.4740E-02 , 5.9121E-02, CLDBDR    259
     X   3.0903E-02 , 5.6207E-02 , 9.2149E-02 , 1.2538E-01 , 1.4805E-01, CLDBDR    260
     X   3.6622E-02 , 8.1639E-02 , 1.6582E-01 , 2.8536E-01 , 4.4432E-01, CLDBDR    261
     X   4.1085E-02 , 1.1829E-01 , 3.1424E-01 , 7.2430E-01 , 1.5853E+00, CLDBDR    262
     X   4.5844E-02 , 1.5420E-01 , 5.0390E-01 , 1.5769E+00 , 5.7206E+00/ CLDBDR    263
C     DATA KPN,XLAM,WZERO/  427,  2.75, 1.00000E+00/                      CLDBDR    264
      DATA(RFL5(I,1,1),I=1,45)                                            CLDBDR    265
     X / 5.4773E-04 , 8.6908E-04 , 1.2643E-03 , 1.5769E-03 , 1.8229E-03, CLDBDR    266
     X   6.2783E-04 , 9.1084E-04 , 1.2716E-03 , 1.6691E-03 , 2.4475E-03, CLDBDR    267
     X   5.7365E-04 , 9.2491E-04 , 1.3430E-03 , 1.6156E-03 , 1.6811E-03, CLDBDR    268
     X   5.5865E-04 , 8.6923E-04 , 1.2520E-03 , 1.5747E-03 , 1.9052E-03, CLDBDR    269
     X   5.2488E-04 , 8.8420E-04 , 1.3611E-03 , 1.7849E-03 , 2.1415E-03, CLDBDR    270
     X   4.5873E-04 , 7.4351E-04 , 1.1143E-03 , 1.4551E-03 , 1.8198E-03, CLDBDR    271
     X   6.2050E-04 , 9.9749E-04 , 1.4640E-03 , 1.8273E-03 , 2.0795E-03, CLDBDR    272
     X   6.6493E-04 , 9.4753E-04 , 1.2999E-03 , 1.6780E-03 , 2.4237E-03, CLDBDR    273
     X   4.3178E-04 , 7.7318E-04 , 1.2855E-03 , 1.8771E-03 , 2.6672E-03/ CLDBDR    274
C     DATA KPN,XLAM,WZERO/  427,  2.75, 8.66000E-01/                      CLDBDR    275
      DATA(RFL5(I,1,2),I=1,45)                                            CLDBDR    276
     X / 7.5118E-04 , 8.1746E-04 , 8.4178E-04 , 7.8933E-04 , 7.7489E-04, CLDBDR    277
     X   4.9333E-04 , 7.2599E-04 , 8.1920E-04 , 5.6336E-04 , 1.8009E-04, CLDBDR    278
     X   5.6445E-04 , 8.2179E-04 , 1.0876E-03 , 1.2141E-03 , 1.2153E-03, CLDBDR    279
     X   7.1208E-04 , 9.9927E-04 , 1.3357E-03 , 1.6462E-03 , 2.1788E-03, CLDBDR    280
     X   7.1629E-04 , 1.2076E-03 , 1.8132E-03 , 2.2084E-03 , 2.2288E-03, CLDBDR    281
     X   1.0120E-03 , 1.5881E-03 , 2.2526E-03 , 2.6661E-03 , 2.7682E-03, CLDBDR    282
     X   9.4973E-04 , 1.7477E-03 , 2.9083E-03 , 4.0415E-03 , 4.9357E-03, CLDBDR    283
     X   1.0398E-03 , 2.0536E-03 , 3.5957E-03 , 5.0620E-03 , 5.8012E-03, CLDBDR    284
     X   1.0902E-03 , 2.2364E-03 , 4.1711E-03 , 6.5639E-03 , 9.2685E-03/ CLDBDR    285
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C     DATA KPN,XLAM,WZERO/  427, 2.75, 5.00000E-01/                       CLDBDR   286
      DATA(RFL5(I,1,3),I=1,45)                                            CLDBDR   287
     X / 8.8451E-04 , 5.6244E-04 , 4.0234E-04 , 3.6462E-04 , 6.7453E-04,  CLDBDR   288
     X   9.0642E-04 , 7.3248E-04 , 6.3298E-04 , 6.2908E-04 , 1.0495E-03,  CLDBDR   289
     X   7.1941E-04 , 9.9667E-04 , 1.1849E-03 , 1.0643E-03 , 6.8629E-04,  CLDBDR   290
     X   1.0519E-03 , 1.6260E-03 , 2.1480E-03 , 2.1274E-03 , 1.4890E-03,  CLDBDR   291
     X   1.7983E-03 , 2.5005E-03 , 3.3364E-03 , 4.1638E-03 , 5.7429E-03,  CLDBDR   292
     X   1.9396E-03 , 3.6323E-03 , 6.0243E-03 , 8.0178E-03 , 8.6522E-03,  CLDBDR   293
     X   2.5303E-03 , 5.6484E-03 , 1.1095E-02 , 1.7274E-02 , 2.1269E-02,  CLDBDR   294
     X   2.8208E-03 , 7.2811E-03 , 1.7171E-02 , 3.4485E-02 , 6.3324E-02,  CLDBDR   295
     X   3.2883E-03 , 1.0471E-02 , 2.9484E-02 , 6.6441E-02 , 1.2072E-01/  CLDBDR   296
C     DATA KPN,XLAM,WZERO/  427, 2.75, 1.73600E-01/                       CLDBDR   297
      DATA(RFL5(I,1,4),I=1,45)                                            CLDBDR   298
     X / 7.9174E-04 , 1.4845E-03 , 2.0524E-03 , 1.6054E-03 , 5.0211E-04,  CLDBDR   299
     X   8.5581E-04 , 1.3496E-03 , 1.9477E-03 , 2.4010E-03 , 2.7232E-03,  CLDBDR   300
     X   1.1019E-03 , 1.4719E-03 , 1.9648E-03 , 2.6504E-03 , 4.6203E-03,  CLDBDR   301
     X   1.2554E-03 , 1.5926E-03 , 2.0974E-03 , 3.0019E-03 , 6.4323E-03,  CLDBDR   302
     X   2.4460E-03 , 3.4192E-03 , 4.8724E-03 , 7.2885E-03 , 1.5216E-02,  CLDBDR   303
     X   3.5899E-03 , 6.4264E-03 , 1.1072E-02 , 1.7943E-02 , 3.2504E-02,  CLDBDR   304
     X   3.9642E-03 , 1.0459E-02 , 2.5781E-02 , 5.6485E-02 , 1.2337E-01,  CLDBDR   305
     X   5.0367E-03 , 1.9240E-02 , 6.7252E-02 , 2.0078E-01 , 5.5130E-01,  CLDBDR   306
     X   6.1330E-03 , 2.8126E-02 , 1.2582E-01 , 5.4314E-01 , 2.7604E+00/  CLDBDR   307
C     DATA KPN,XLAM,WZERO/  428, 2.85, 1.00000E+00/                       CLDBDR   308
      DATA(RFL6(I,1,1),I=1,45)                                            CLDBDR   309
     X / 6.5579E-04 , 7.8007E-04 , 9.2441E-04 , 1.1005E-03 , 1.6732E-03,  CLDBDR   310
     X   6.8788E-04 , 8.5770E-04 , 1.0344E-03 , 1.1846E-03 , 1.5459E-03,  CLDBDR   311
     X   6.5625E-04 , 8.6321E-04 , 1.0696E-03 , 1.1963E-03 , 1.3765E-03,  CLDBDR   312
     X   6.0999E-04 , 7.5593E-04 , 9.2363E-04 , 1.1115E-03 , 1.6411E-03,  CLDBDR   313
     X   6.7913E-04 , 8.1517E-04 , 9.5655E-04 , 1.0877E-03 , 1.4685E-03,  CLDBDR   314
     X   7.2494E-04 , 8.4712E-04 , 9.9515E-04 , 1.1949E-03 , 1.8975E-03,  CLDBDR   315
     X   6.7821E-04 , 8.4967E-04 , 1.0193E-03 , 1.1390E-03 , 1.3951E-03,  CLDBDR   316
     X   6.6690E-04 , 8.2228E-04 , 9.8308E-04 , 1.1213E-03 , 1.4712E-03,  CLDBDR   317
     X   7.3536E-04 , 8.4989E-04 , 9.7222E-04 , 1.1035E-03 , 1.5599E-03/  CLDBDR   318
C     DATA KPN,XLAM,WZERO/  428, 2.85, 8.66000E-01/                       CLDBDR   319
      DATA(RFL6(I,1,2),I=1,45)                                            CLDBDR   320
     X / 5.8635E-04 , 8.1882E-04 , 9.7887E-04 , 8.8013E-04 , 5.6286E-04,  CLDBDR   321
     X   6.0742E-04 , 7.2260E-04 , 7.6967E-04 , 6.7172E-04 , 4.9577E-04,  CLDBDR   322
     X   6.3340E-04 , 8.2803E-04 , 9.8242E-04 , 9.8011E-04 , 8.7136E-04,  CLDBDR   323
     X   6.8677E-04 , 8.7159E-04 , 1.0391E-03 , 1.1126E-03 , 1.2127E-03,  CLDBDR   324
     X   7.4732E-04 , 1.0527E-03 , 1.3620E-03 , 1.5157E-03 , 1.5738E-03,  CLDBDR   325
     X   7.4932E-04 , 9.8769E-04 , 1.3128E-03 , 1.7939E-03 , 3.2802E-03,  CLDBDR   326
     X   9.2476E-04 , 1.2135E-03 , 1.5098E-03 , 1.7170E-03 , 2.0599E-03,  CLDBDR   327
     X   8.3896E-04 , 1.1450E-03 , 1.6028E-03 , 2.3829E-03 , 5.0623E-03,  CLDBDR   328
     X   7.2247E-04 , 1.1813E-03 , 1.8736E-03 , 2.8370E-03 , 4.9491E-03/  CLDBDR   329
C     DATA KPN,XLAM,WZERO/  428, 2.85, 5.00000E-01/                       CLDBDR   330
      DATA(RFL6(I,1,3),I=1,45)                                            CLDBDR   331
     X / 7.4576E-04 , 5.8585E-04 , 5.4311E-04 , 6.9888E-04 , 2.2081E-03,  CLDBDR   332
     X   4.5287E-04 , 6.6070E-04 , 8.8152E-04 , 1.0035E-03 , 1.0484E-03,  CLDBDR   333
     X   5.9535E-04 , 6.5035E-04 , 7.5598E-04 , 1.0012E-03 , 2.1838E-03,  CLDBDR   334
     X   8.7711E-04 , 7.6898E-04 , 7.3901E-04 , 8.5629E-04 , 1.8324E-03,  CLDBDR   335
     X   1.1411E-03 , 1.5088E-03 , 1.8541E-03 , 2.0042E-03 , 2.1152E-03,  CLDBDR   336
     X   8.1721E-04 , 1.5524E-03 , 2.6721E-03 , 3.8556E-03 , 4.9271E-03,  CLDBDR   337
     X   1.3445E-03 , 2.5426E-03 , 4.4480E-03 , 6.7856E-03 , 9.9293E-03,  CLDBDR   338
     X   1.1706E-03 , 2.8712E-03 , 6.5034E-03 , 1.2804E-02 , 2.4021E-02,  CLDBDR   339
     X   1.4317E-03 , 3.4986E-03 , 8.3823E-03 , 1.9569E-02 , 5.4852E-02/  CLDBDR   340
C     DATA KPN,XLAM,WZERO/  428, 2.85, 1.73600E-01/                       CLDBDR   341
      DATA(RFL6(I,1,4),I=1,45)                                            CLDBDR   342
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     X / 1.4432E-03 , 1.4302E-03 , 1.5076E-03 , 1.8093E-03 , 3.5716E-03, CLDBDR   343
     X   1.3499E-03 , 1.8646E-03 , 2.5667E-03 , 3.5513E-03 , 6.2812E-03, CLDBDR   344
     X   1.5644E-03 , 1.6991E-03 , 1.8934E-03 , 2.2423E-03 , 3.7992E-03, CLDBDR   345
     X   3.3582E-04 , 7.6495E-04 , 1.6042E-03 , 2.9073E-03 , 4.9624E-03, CLDBDR   346
     X   1.1219E-03 , 1.4217E-03 , 1.8146E-03 , 2.3751E-03 , 4.1389E-03, CLDBDR   347
     X   1.0685E-03 , 2.4392E-03 , 4.9467E-03 , 8.0977E-03 , 1.0875E-02, CLDBDR   348
     X   2.7523E-03 , 5.3205E-03 , 1.0212E-02 , 1.9566E-02 , 4.7256E-02, CLDBDR   349
     X   3.1640E-03 , 8.9367E-03 , 2.4474E-02 , 6.3939E-02 , 1.9213E-01, CLDBDR   350
     X   3.3333E-03 , 1.2574E-02 , 4.7551E-02 , 1.8285E-01 , 9.2023E-01/ CLDBDR   351
C     DATA KPN,XLAM,WZERO/  432, 3.20, 1.00000E+00/                      CLDBDR   352
      DATA(RFL7(I,1,1),I=1,45)                                           CLDBDR   353
     X / 2.2381E-03 , 2.5124E-03 , 2.8035E-03 , 3.1294E-03 , 4.4226E-03, CLDBDR   354
     X   2.4909E-03 , 2.6017E-03 , 2.7447E-03 , 2.9864E-03 , 4.3760E-03, CLDBDR   355
     X   2.2896E-03 , 2.5921E-03 , 2.9325E-03 , 3.3526E-03 , 4.9532E-03, CLDBDR   356
     X   2.2124E-03 , 2.3881E-03 , 2.6135E-03 , 2.9711E-03 , 4.6150E-03, CLDBDR   357
     X   2.1736E-03 , 2.3962E-03 , 2.6508E-03 , 2.9872E-03 , 4.4209E-03, CLDBDR   358
     X   2.2319E-03 , 2.3962E-03 , 2.6208E-03 , 3.0054E-03 , 4.7983E-03, CLDBDR   359
     X   2.7621E-03 , 2.7398E-03 , 2.8569E-03 , 3.3162E-03 , 6.0492E-03, CLDBDR   360
     X   2.3798E-03 , 2.6678E-03 , 3.0376E-03 , 3.6052E-03 , 5.8875E-03, CLDBDR   361
     X   2.3686E-03 , 2.5606E-03 , 2.8162E-03 , 3.2388E-03 , 5.1581E-03/ CLDBDR   362
C     DATA KPN,XLAM,WZERO/  432, 3.20, 8.66000E-01/                      CLDBDR   363
      DATA(RFL7(I,1,2),I=1,45)                                           CLDBDR   364
     X / 2.5813E-03 , 3.0038E-03 , 3.1291E-03 , 2.6698E-03 , 1.9251E-03, CLDBDR   365
     X   2.6401E-03 , 2.7600E-03 , 2.8902E-03 , 3.0721E-03 , 4.2584E-03, CLDBDR   366
     X   3.0477E-03 , 2.8996E-03 , 2.8158E-03 , 2.8774E-03 , 4.1238E-03, CLDBDR   367
     X   2.3955E-03 , 2.8588E-03 , 3.2771E-03 , 3.5198E-03 , 4.1929E-03, CLDBDR   368
     X   2.0123E-03 , 2.9603E-03 , 3.9775E-03 , 4.5483E-03 , 4.7496E-03, CLDBDR   369
     X   2.3615E-03 , 3.3798E-03 , 4.5471E-03 , 5.5008E-03 , 6.7912E-03, CLDBDR   370
     X   2.2137E-03 , 3.2347E-03 , 4.4515E-03 , 5.5288E-03 , 7.0603E-03, CLDBDR   371
     X   2.3439E-03 , 3.4192E-03 , 4.8860E-03 , 6.7919E-03 , 1.1297E-02, CLDBDR   372
     X   2.2418E-03 , 3.5387E-03 , 5.2920E-03 , 7.2229E-03 , 1.0369E-02/ CLDBDR   373
C     DATA KPN,XLAM,WZERO/  432, 3.20, 5.00000E-01/                      CLDBDR   374
      DATA(RFL7(I,1,3),I=1,45)                                           CLDBDR   375
     X / 2.4118E-03 , 3.7976E-03 , 5.0827E-03 , 5.0473E-03 , 3.4680E-03, CLDBDR   376
     X   2.5424E-03 , 3.5279E-03 , 4.3203E-03 , 4.2175E-03 , 3.2935E-03, CLDBDR   377
     X   2.6502E-03 , 3.1842E-03 , 3.6294E-03 , 3.8127E-03 , 4.2968E-03, CLDBDR   378
     X   3.0587E-03 , 3.5391E-03 , 4.0700E-03 , 4.6808E-03 , 6.8123E-03, CLDBDR   379
     X   2.9507E-03 , 4.3131E-03 , 5.9667E-03 , 7.5186E-03 , 9.9249E-03, CLDBDR   380
     X   3.1184E-03 , 4.9601E-03 , 7.2599E-03 , 9.1735E-03 , 1.0895E-02, CLDBDR   381
     X   3.8802E-03 , 6.3366E-03 , 1.0015E-02 , 1.5050E-02 , 2.5831E-02, CLDBDR   382
     X   4.8843E-03 , 7.3526E-03 , 1.1325E-02 , 1.8439E-02 , 4.2498E-02, CLDBDR   383
     X   4.7470E-03 , 8.8773E-03 , 1.5891E-02 , 2.6479E-02 , 4.8292E-02/ CLDBDR   384
C     DATA KPN,XLAM,WZERO/  432, 3.20, 1.73600E-01/                      CLDBDR   385
      DATA(RFL7(I,1,4),I=1,45)                                           CLDBDR   386
     X / 2.6928E-03 , 4.0262E-03 , 5.8235E-03 , 8.0003E-03 , 1.2530E-02, CLDBDR   387
     X   3.3211E-03 , 4.2607E-03 , 5.0165E-03 , 5.0734E-03 , 4.7737E-03, CLDBDR   388
     X   3.3930E-03 , 4.0589E-03 , 4.6547E-03 , 4.9827E-03 , 5.8714E-03, CLDBDR   389
     X   3.9449E-03 , 4.7291E-03 , 5.7623E-03 , 7.3286E-03 , 1.2860E-02, CLDBDR   390
     X   4.3951E-03 , 6.7266E-03 , 9.7828E-03 , 1.3060E-02 , 1.8554E-02, CLDBDR   391
     X   5.4314E-03 , 8.7131E-03 , 1.3673E-02 , 2.0817E-02 , 3.7717E-02, CLDBDR   392
     X   6.8674E-03 , 1.2367E-02 , 2.1316E-02 , 3.4192E-02 , 6.0009E-02, CLDBDR   393
     X   8.5311E-03 , 1.7241E-02 , 3.4637E-02 , 6.9626E-02 , 1.7728E-01, CLDBDR   394
     X   8.7021E-03 , 2.0829E-02 , 5.4661E-02 , 1.7301E-01 , 1.0120E+00/ CLDBDR   395
C     DATA KPN,XLAM,WZERO/  435, 3.50, 1.00000E+00/                      CLDBDR   396
      DATA(RFL8(I,1,1),I=1,45)                                           CLDBDR   397
     X / 3.9995E-02 , 3.8324E-02 , 3.5939E-02 , 3.2725E-02 , 3.5524E-02, CLDBDR   398
     X   4.2419E-02 , 4.6002E-02 , 4.5976E-02 , 3.9783E-02 , 3.2545E-02, CLDBDR   399
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      X   4.5036E-02 , 4.6258E-02 , 4.4954E-02 , 3.9769E-02 , 3.6812E-02, CLDBDR
      X   5.0371E-02 , 4.4566E-02 , 3.9107E-02 , 3.4185E-02 , 3.7512E-02, CLDBDR
      X   5.1055E-02 , 4.6899E-02 , 4.1902E-02 , 3.5924E-02 , 3.5849E-02, CLDBDR
      X   4.3450E-02 , 4.4222E-02 , 4.3337E-02 , 3.9980E-02 , 4.1299E-02, CLDBDR
      X   4.2486E-02 , 4.3113E-02 , 4.1873E-02 , 3.7850E-02 , 3.7434E-02, CLDBDR
      X   4.3339E-02 , 4.0787E-02 , 3.7949E-02 , 3.4960E-02 , 3.9936E-02, CLDBDR
      X   4.5118E-02 , 4.3892E-02 , 4.1443E-02 , 3.7401E-02 , 3.8976E-02/ CLDBDR
C      DATA KPN,XLAM,WZERO/  435,  3.50, 8.66000E-01/                     CLDBDR
       DATA(RFL8(I,1,2),I=1,45)                                           CLDBDR
      X / 5.2061E-02 , 5.8214E-02 , 5.9052E-02 , 5.0329E-02 , 3.8162E-02, CLDBDR
      X   6.2870E-02 , 6.1438E-02 , 5.6146E-02 , 4.5681E-02 , 3.7177E-02, CLDBDR
      X   5.5855E-02 , 5.3309E-02 , 4.8929E-02 , 4.2177E-02 , 4.0516E-02, CLDBDR
      X   4.7769E-02 , 4.8704E-02 , 4.7508E-02 , 4.3096E-02 , 4.2705E-02, CLDBDR
      X   4.8670E-02 , 5.0254E-02 , 4.9573E-02 , 4.5353E-02 , 4.5076E-02, CLDBDR
      X   3.9856E-02 , 4.6006E-02 , 5.0363E-02 , 5.0417E-02 , 5.3297E-02, CLDBDR
      X   4.0213E-02 , 4.6819E-02 , 5.2531E-02 , 5.5576E-02 , 6.6054E-02, CLDBDR
      X   4.4734E-02 , 5.0139E-02 , 5.5470E-02 , 6.0566E-02 , 8.1476E-02, CLDBDR
      X   3.9976E-02 , 5.1867E-02 , 6.3711E-02 , 7.1337E-02 , 8.3797E-02/ CLDBDR
C      DATA KPN,XLAM,WZERO/  435,  3.50, 5.00000E-01/                     CLDBDR
       DATA(RFL8(I,1,3),I=1,45)                                           CLDBDR
      X / 5.2385E-02 , 7.1243E-02 , 9.1024E-02 , 1.0445E-01 , 1.2205E-01, CLDBDR
      X   5.3326E-02 , 7.3399E-02 , 9.1026E-02 , 9.3612E-02 , 8.3417E-02, CLDBDR
      X   4.4951E-02 , 5.8311E-02 , 6.9011E-02 , 6.9362E-02 , 6.3389E-02, CLDBDR
      X   4.5231E-02 , 5.3367E-02 , 6.0240E-02 , 6.3233E-02 , 7.2502E-02, CLDBDR
      X   4.5041E-02 , 5.6263E-02 , 6.7008E-02 , 7.3723E-02 , 8.7425E-02, CLDBDR
      X   4.6345E-02 , 6.1387E-02 , 7.7188E-02 , 8.8923E-02 , 1.0859E-01, CLDBDR
      X   4.8949E-02 , 7.4661E-02 , 1.0795E-01 , 1.4261E-01 , 1.9859E-01, CLDBDR
      X   5.5234E-02 , 8.7770E-02 , 1.3405E-01 , 1.9208E-01 , 3.0603E-01, CLDBDR
      X   5.3656E-02 , 9.1525E-02 , 1.4972E-01 , 2.2876E-01 , 3.8529E-01/ CLDBDR
C      DATA KPN,XLAM,WZERO/  435,  3.50, 1.73600E-01/                     CLDBDR
       DATA(RFL8(I,1,4),I=1,45)                                           CLDBDR
      X / 3.8284E-02 , 7.0000E-02 , 1.1371E-01 , 1.4914E-01 , 1.6055E-01, CLDBDR
      X   4.3095E-02 , 6.3699E-02 , 9.1284E-02 , 1.2477E-01 , 1.9609E-01, CLDBDR
      X   4.2916E-02 , 5.4721E-02 , 6.8268E-02 , 8.2664E-02 , 1.1923E-01, CLDBDR
      X   4.1874E-02 , 5.6292E-02 , 7.1332E-02 , 8.1704E-02 , 9.6526E-02, CLDBDR
      X   4.7868E-02 , 6.5886E-02 , 8.7022E-02 , 1.0750E-01 , 1.4676E-01, CLDBDR
      X   5.1965E-02 , 7.6822E-02 , 1.1108E-01 , 1.5579E-01 , 2.5991E-01, CLDBDR
      X   5.6165E-02 , 9.8673E-02 , 1.6601E-01 , 2.6020E-01 , 4.4713E-01, CLDBDR
      X   6.3932E-02 , 1.3537E-01 , 2.6853E-01 , 4.7584E-01 , 8.4918E-01, CLDBDR
      X   7.3568E-02 , 1.6248E-01 , 3.4828E-01 , 7.1356E-01 , 1.6881E+00/ CLDBDR
C      DATA KPN,XLAM,WZERO/  440,  4.00, 1.00000E+00/                     CLDBDR
       DATA(RFL9(I,1,1),I=1,45)                                           CLDBDR
      X / 5.7056E-02 , 6.6629E-02 , 6.9572E-02 , 5.9369E-02 , 4.2621E-02, CLDBDR
      X   5.6099E-02 , 6.4320E-02 , 6.7310E-02 , 5.9875E-02 , 4.8514E-02, CLDBDR
      X   6.6702E-02 , 6.5828E-02 , 6.3197E-02 , 5.8241E-02 , 6.2522E-02, CLDBDR
      X   6.9785E-02 , 7.0618E-02 , 6.6541E-02 , 5.5368E-02 , 4.5332E-02, CLDBDR
      X   6.3429E-02 , 6.8923E-02 , 6.8352E-02 , 5.7612E-02 , 4.4219E-02, CLDBDR
      X   5.9453E-02 , 6.3887E-02 , 6.4337E-02 , 5.7915E-02 , 5.2577E-02, CLDBDR
      X   6.3321E-02 , 6.4344E-02 , 6.2581E-02 , 5.6645E-02 , 5.6098E-02, CLDBDR
      X   7.4265E-02 , 6.9261E-02 , 6.3393E-02 , 5.6645E-02 , 6.1000E-02, CLDBDR
      X   7.9859E-02 , 8.9348E-02 , 9.0412E-02 , 7.6420E-02 , 5.6797E-02/ CLDBDR
C      DATA KPN,XLAM,WZERO/  440,  4.00, 8.66000E-01/                     CLDBDR
       DATA(RFL9(I,1,2),I=1,45)                                           CLDBDR
      X / 6.9259E-02 , 7.5671E-02 , 7.7308E-02 , 7.0302E-02 , 6.3925E-02, CLDBDR
      X   7.1106E-02 , 8.3547E-02 , 8.7641E-02 , 7.4920E-02 , 5.3569E-02, CLDBDR
      X   8.1744E-02 , 8.2238E-02 , 7.8765E-02 , 6.9495E-02 , 6.5715E-02, CLDBDR
      X   7.4577E-02 , 7.7389E-02 , 7.5623E-02 , 6.6669E-02 , 6.0388E-02, CLDBDR
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      X   7.6929E-02 , 8.1116E-02 , 8.0645E-02 , 7.2508E-02 , 6.7312E-02, CLDBDR
      X   7.5559E-02 , 7.9429E-02 , 7.9236E-02 , 7.2368E-02 , 6.9963E-02, CLDBDR
      X   7.1461E-02 , 8.3150E-02 , 9.0703E-02 , 8.8513E-02 , 8.7244E-02, CLDBDR
      X   6.8598E-02 , 8.5133E-02 , 9.7502E-02 , 9.6936E-02 , 9.1597E-02, CLDBDR
      X   7.3721E-02 , 8.9882E-02 , 1.0252E-01 , 1.0418E-01 , 1.0605E-01/ CLDBDR
C      DATA KPN,XLAM,WZERO/  440, 4.00, 5.00000E-01/                     CLDBDR
       DATA(RFL9(I,1,3),I=1,45)                                          CLDBDR
      X / 8.0568E-02 , 9.1765E-02 , 1.0024E-01 , 1.0231E-01 , 1.1516E-01, CLDBDR
      X   7.8142E-02 , 9.4849E-02 , 1.0484E-01 , 9.8087E-02 , 8.2858E-02, CLDBDR
      X   7.7449E-02 , 8.8103E-02 , 9.2628E-02 , 8.4778E-02 , 7.4174E-02, CLDBDR
      X   7.4176E-02 , 8.6320E-02 , 9.4180E-02 , 9.1932E-02 , 9.0656E-02, CLDBDR
      X   8.5939E-02 , 1.0204E-01 , 1.1336E-01 , 1.1227E-01 , 1.1150E-01, CLDBDR
      X   8.7706E-02 , 1.0866E-01 , 1.2783E-01 , 1.3783E-01 , 1.5769E-01, CLDBDR
      X   8.0221E-02 , 1.1780E-01 , 1.6014E-01 , 1.9014E-01 , 2.1724E-01, CLDBDR
      X   9.9521E-02 , 1.4557E-01 , 2.0498E-01 , 2.7162E-01 , 4.0271E-01, CLDBDR
      X   9.2745E-02 , 1.5082E-01 , 2.3497E-01 , 3.4132E-01 , 5.4450E-01/ CLDBDR
C      DATA KPN,XLAM,WZERO/  440, 4.00, 1.73600E-01/                     CLDBDR
       DATA(RFL9(I,1,4),I=1,45)                                          CLDBDR
      X / 7.1144E-02 , 9.1484E-02 , 1.1183E-01 , 1.2556E-01 , 1.5023E-01, CLDBDR
      X   6.5636E-02 , 8.7610E-02 , 1.1128E-01 , 1.3009E-01 , 1.6269E-01, CLDBDR
      X   6.3826E-02 , 7.9407E-02 , 9.4066E-02 , 1.0268E-01 , 1.2020E-01, CLDBDR
      X   6.0787E-02 , 7.8909E-02 , 9.6056E-02 , 1.0465E-01 , 1.1526E-01, CLDBDR
      X   6.7155E-02 , 9.3466E-02 , 1.2242E-01 , 1.4449E-01 , 1.7479E-01, CLDBDR
      X   7.4152E-02 , 1.0687E-01 , 1.4944E-01 , 1.9961E-01 , 3.0746E-01, CLDBDR
      X   8.9782E-02 , 1.4624E-01 , 2.3114E-01 , 3.4908E-01 , 6.0833E-01, CLDBDR
      X   8.9324E-02 , 1.8376E-01 , 3.6226E-01 , 6.6617E-01 , 1.3467E+00, CLDBDR
      X   9.6656E-02 , 2.2381E-01 , 5.1271E-01 , 1.1642E+00 , 3.2859E+00/ CLDBDR
C      DATA KPN,XLAM,WZERO/  450, 5.00, 1.00000E+00/                     CLDBDR
       DATA(RFL10(I,1,1),I=1,45)                                         CLDBDR
      X / 3.0860E-02 , 3.3706E-02 , 3.4964E-02 , 3.3258E-02 , 3.3592E-02, CLDBDR
      X   2.9041E-02 , 3.2556E-02 , 3.4322E-02 , 3.2562E-02 , 3.1579E-02, CLDBDR
      X   3.2634E-02 , 3.8256E-02 , 4.0401E-02 , 3.5373E-02 , 2.6824E-02, CLDBDR
      X   2.9870E-02 , 3.5884E-02 , 3.8755E-02 , 3.4560E-02 , 2.6475E-02, CLDBDR
      X   3.6096E-02 , 3.9507E-02 , 4.0115E-02 , 3.5719E-02 , 3.0851E-02, CLDBDR
      X   3.3269E-02 , 3.4079E-02 , 3.3990E-02 , 3.2596E-02 , 3.6534E-02, CLDBDR
      X   3.1698E-02 , 3.9824E-02 , 4.4590E-02 , 4.0548E-02 , 3.0629E-02, CLDBDR
      X   3.1945E-02 , 3.6592E-02 , 3.8825E-02 , 3.6015E-02 , 3.2214E-02, CLDBDR
      X   3.7706E-02 , 3.8799E-02 , 3.8327E-02 , 3.5440E-02 , 3.6277E-02/ CLDBDR
C      DATA KPN,XLAM,WZERO/  450, 5.00, 8.66000E-01/                     CLDBDR
       DATA(RFL10(I,1,2),I=1,45)                                         CLDBDR
      X / 2.4429E-02 , 3.3795E-02 , 4.1313E-02 , 4.0358E-02 , 3.1696E-02, CLDBDR
      X   3.4698E-02 , 3.9582E-02 , 4.1167E-02 , 3.6316E-02 , 2.9056E-02, CLDBDR
      X   3.4683E-02 , 4.1094E-02 , 4.3614E-02 , 3.7961E-02 , 2.7992E-02, CLDBDR
      X   3.6829E-02 , 4.2934E-02 , 4.5361E-02 , 4.0192E-02 , 3.1567E-02, CLDBDR
      X   3.9340E-02 , 4.5389E-02 , 4.9049E-02 , 4.7334E-02 , 4.5974E-02, CLDBDR
      X   3.8716E-02 , 4.4921E-02 , 4.8950E-02 , 4.7880E-02 , 4.7629E-02, CLDBDR
      X   3.6380E-02 , 4.9511E-02 , 5.9900E-02 , 5.8573E-02 , 4.7119E-02, CLDBDR
      X   4.1265E-02 , 5.1878E-02 , 6.1588E-02 , 6.6314E-02 , 7.4155E-02, CLDBDR
      X   3.7312E-02 , 5.1642E-02 , 6.5663E-02 , 7.1850E-02 , 7.3425E-02/ CLDBDR
C      DATA KPN,XLAM,WZERO/  450, 5.00, 5.00000E-01/                     CLDBDR
       DATA(RFL10(I,1,3),I=1,45)                                         CLDBDR
      X / 4.0185E-02 , 4.5309E-02 , 4.9320E-02 , 5.0795E-02 , 5.9181E-02, CLDBDR
      X   4.2358E-02 , 5.0768E-02 , 5.6769E-02 , 5.6264E-02 , 5.5279E-02, CLDBDR
      X   4.4703E-02 , 4.9749E-02 , 5.2001E-02 , 4.8800E-02 , 4.6592E-02, CLDBDR
      X   4.1983E-02 , 5.0831E-02 , 5.7154E-02 , 5.6458E-02 , 5.4310E-02, CLDBDR
      X   4.5331E-02 , 6.1865E-02 , 7.5921E-02 , 7.6972E-02 , 6.7106E-02, CLDBDR
      X   4.5283E-02 , 6.6351E-02 , 8.7983E-02 , 9.7564E-02 , 9.5352E-02, CLDBDR
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     X    5.4956E-02 , 8.3788E-02 , 1.1842E-01 , 1.4651E-01 , 1.7526E-01, CLDBDR    514
     X    5.6161E-02 , 9.6111E-02 , 1.5396E-01 , 2.1998E-01 , 3.1559E-01, CLDBDR    515
     X    5.6652E-02 , 1.0848E-01 , 1.9164E-01 , 2.9381E-01 , 4.2778E-01/ CLDBDR    516
C     DATA KPN,XLAM,WZERO/  450, 5.00, 1.73600E-01/                      CLDBDR    517
      DATA(RFL10(I,1,4),I=1,45)                                          CLDBDR    518
     X / 3.0171E-02 , 4.0968E-02 , 5.2498E-02 , 6.0945E-02 , 7.3305E-02, CLDBDR    519
     X    3.0411E-02 , 4.0016E-02 , 5.0964E-02 , 6.1708E-02 , 8.5349E-02, CLDBDR    520
     X    3.1124E-02 , 4.1387E-02 , 5.2687E-02 , 6.2451E-02 , 8.1067E-02, CLDBDR    521
     X    3.4008E-02 , 4.6370E-02 , 5.8683E-02 , 6.5175E-02 , 7.0335E-02, CLDBDR    522
     X    4.1566E-02 , 5.8808E-02 , 7.8585E-02 , 9.5280E-02 , 1.2007E-01, CLDBDR    523
     X    4.3259E-02 , 7.0946E-02 , 1.0915E-01 , 1.5036E-01 , 2.0957E-01, CLDBDR    524
     X    5.8935E-02 , 1.0602E-01 , 1.8261E-01 , 2.9294E-01 , 5.1499E-01, CLDBDR    525
     X    5.8149E-02 , 1.3646E-01 , 3.0546E-01 , 6.3216E-01 , 1.4125E+00, CLDBDR    526
     X    6.0197E-02 , 1.6701E-01 , 4.5542E-01 , 1.2160E+00 , 3.9358E+00/ CLDBDR    527
      DO 20 I = 1,4                                                      CLDBDR    528
      ITHIN = I                                                          CLDBDR    529
      IF(CTHIN .GT. TCTHIN(I)) GO TO 30                                  CLDBDR    530
   20 CONTINUE                                                           CLDBDR    531
   30 DO 40 I = 1,5                                                      CLDBDR    532
      ITHOUT = I                                                         CLDBDR    533
      IF(CTHOUT .GT. TCTHOUT(I)) GO TO 50                                CLDBDR    534
   40 CONTINUE                                                           CLDBDR    535
   50 DO 60 I = 1,9                                                      CLDBDR    536
      IPHOUT = I                                                         CLDBDR    537
      IF( CPHOUT .LT. TCPHOUT(I)) GO TO 70                               CLDBDR    538
   60 CONTINUE                                                           CLDBDR    539
   70 CONTINUE                                                           CLDBDR    540
      DO 80 I = 2,10                                                     CLDBDR    541
      ILAM = I - 1                                                       CLDBDR    542
      IF(ALAM .LT. ALAMT(I)) GO TO 90                                    CLDBDR    543
   80 CONTINUE                                                           CLDBDR    544
   90 CONTINUE                                                           CLDBDR    545
      XLAM = (ALAM - ALAMT(ILAM)) / (ALAMT(ILAM+1) - ALAMT(ILAM))        CLDBDR    546
      GO TO(110,120,130,140,150,160,170,180,190 ) ILAM                   CLDBDR    547
  110 CLDBDR = RFL1(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    548
    1  + (RFL2(ITHOUT,IPHOUT,ITHIN) - RFL1(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    549
      RETURN                                                             CLDBDR    550
  120 CLDBDR = RFL2(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    551
    1  + (RFL3(ITHOUT,IPHOUT,ITHIN) - RFL2(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    552
      RETURN                                                             CLDBDR    553
  130 CLDBDR = RFL3(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    554
    1  + (RFL4(ITHOUT,IPHOUT,ITHIN) - RFL3(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    555
      RETURN                                                             CLDBDR    556
  140 CLDBDR = RFL4(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    557
    1  + (RFL5(ITHOUT,IPHOUT,ITHIN) - RFL4(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    558
      RETURN                                                             CLDBDR    559
  150 CLDBDR = RFL5(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    560
    1  + (RFL6(ITHOUT,IPHOUT,ITHIN) - RFL5(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    561
      RETURN                                                             CLDBDR    562
  160 CLDBDR = RFL6(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    563
    1  + (RFL7(ITHOUT,IPHOUT,ITHIN) - RFL6(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    564
      RETURN                                                             CLDBDR    565
  170 CLDBDR = RFL7(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    566
    1  + (RFL8(ITHOUT,IPHOUT,ITHIN) - RFL7(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    567
      RETURN                                                             CLDBDR    568
  180 CLDBDR = RFL8(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    569
    1  + (RFL9(ITHOUT,IPHOUT,ITHIN) - RFL8(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR    570
      RETURN                                                             CLDBDR    571
  190 CLDBDR = RFL9(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR    572
    1  + (RFL10(ITHOUT,IPHOUT,ITHIN) - RFL9(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR    573
      RETURN                                                             CLDBDR    574
      END                                                                CLDBDR    575
```
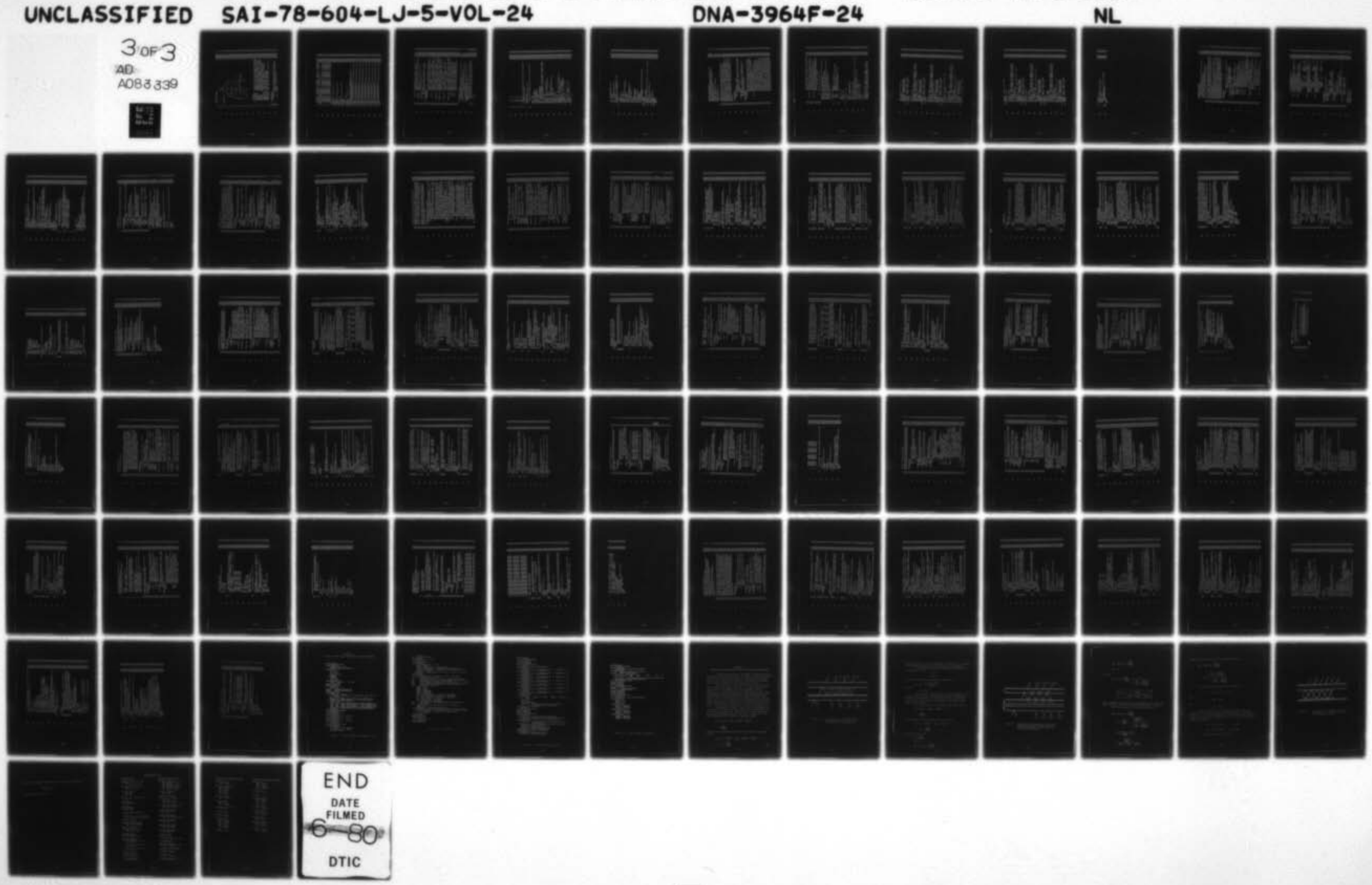
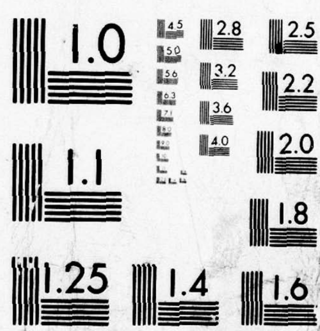

AD-A083 339 SCIENCE APPLICATIONS INC LA JOLLA CA F/G 18/3
THE ROSCOE MANUAL. VOLUME 24. NATURAL CLOUDS (PHYSICAL AND OPTI--ETC(U)
JUL 79 R R JOHNSTON, D E STEVENSON, W A ARON DNA001-76-C-0194
UNCLASSIFIED SAI-78-604-LJ-5-VOL-24 DNA-3964F-24 NL

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1.1
1.25
1.4
1.6
1.8
2.0
2.2
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2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3

```
      SUBROUTINE CLDGEOM                                                CLDGEOM   2
C                                                                       CLDGEOM   3
C                             +                                         CLDGEOM   4
C                             +                                         CLDGEOM   5
C                             +                                         CLDGEOM   6
C                            X+X                                        CLDGEOM   7
C                         X X+ X X                                      CLDGEOM   8
   13 FORMAT(7A5)                                                       CLDGEOM   9
C                        X    +    X                                    CLDGEOM  10
C                      X      +   X   X                                 CLDGEOM  11
C                    X X X X  +     X   X                               CLDGEOM  12
C                   X         +         $                               CLDGEOM  13
C                 X$   X      +     X     X                             CLDGEOM  14
C                X   X              $                                   CLDGEOM  15
C                X   $  $  $ +$  $                                      CLDGEOM  16
C                    X  X  X +      X   $  X                            CLDGEOM  17
C           X              X +        $     X                           CLDGEOM  18
C           $  $  X        X +      $ X                                 CLDGEOM  19
C          X       $       $ +$  $            X                         CLDGEOM  20
C         X       X        X +          X    $                          CLDGEOM  21
C         X                  +        $  $         X                    CLDGEOM  22
C          $         X     X + $  $       X                             CLDGEOM  23
C        X   $  $  $  $ ++++++++++++++++++++++                          CLDGEOM  24
C        X           X    +X            X       $                       CLDGEOM  25
C        X             +                     $                          CLDGEOM  26
C                    +  X    X         X$                               CLDGEOM  27
C         X      +                        $                             CLDGEOM  28
C                            X    X     $                               CLDGEOM  29
C         X+  $ $ $ $ $ $                                               CLDGEOM  30
C                                                                       CLDGEOM  31
C              +                                                        CLDGEOM  32
C                                                                       CLDGEOM  33
C                                                                       CLDGEOM  34
C                                                                       CLDGEOM  35
C        VOCABULARY                                                     CLDGEOM  36
C        XI  (10,20)    X COORD OF THE I(I=1,10) TH SOURCE IN JTH CLOUD CLDGEOM  37
C        ETA (10,20)    Y COORD OF THE I(I=1,10) TH SOURCE IN JTH CLOUD CLDGEOM  38
C        ZETA(10,20)    YZCOORD OF THE I(I=1,10) TH SOURCE IN JTH CLOUD CLDGEOM  39
C        RHOS(10,20)    DISTANCE FROM THE SOURCE TO THE CLOUD CENTER    CLDGEOM  40
C        XID(20)        RECTANGULAR COORD OF DETECTOR W.R.T. JTH CLOUD  CLDGEOM  41
C        ETAD(20)       RECTANGULAR COORD OF DETECTOR W.R.T. JTH CLOUD  CLDGEOM  42
C        ZETAD(20)      RECTANGULAR COORD OF DETECTOR W.R.T. JTH CLOUD  CLDGEOM  43
C        RHOD(20)      DISTANCE OF THE DETECTOR FROM THE JTH CLOUD      CLDGEOM  44
C        CPHI(4,4,20)   DEFINED THE AREA ELEMENTS  (1ST QUAD ONLY.      CLDGEOM  45
C        CTH (4,4,20)   DEFINED THE AREA ELEMENTS  (1ST QUAD ONLY.      CLDGEOM  46
C        CPHIBAR(16,20)  AREAS OVER THE  WHOLE CLOUD                    CLDGEOM  47
C        CTHBAR ( 8,20)  AREAS OVER THE  WHOLE CLOUD                    CLDGEOM  48
C        CRBAR(4,4,20) TO MID PT OF EACH AREA ELEMENT                   CLDGEOM  49
C        CAREA(4,4,20)  FIRST OCTANT AREA - ALL OTHERS ARE SYMMETRIC    CLDGEOM  50
C                                                                       CLDGEOM  51
CLJ                                                                     CLDGEOM  52
CLJ   INPUT PARAMETERS                                                  CLDGEOM  53
CLJ      CLOUD COMMON                                                   CLDGEOM  54
CLJ          NCLOUD = NUMBER OF DETERMINISTIC CLOUDS FOR WHICH THE      CLDGEOM  55
CLJ                   ALTITUDE OF CENTER, SEMI-AXES, AND ORIENTATION    CLDGEOM  56
CLJ                   ARE READ BY SUBROUTINE CLOUDO                     CLDGEOM  57
CLJ           FOR K = 1,NCLOUD,                                         CLDGEOM  58
```

```
     X   5.4956E-02 , 8.3788E-02 , 1.1842E-01 , 1.4651E-01 , 1.7526E-01, CLDBDR
     X   5.6161E-02 , 9.6111E-02 , 1.5396E-01 , 2.1998E-01 , 3.1559E-01, CLDBDR
     X   5.6652E-02 , 1.0848E-01 , 1.9164E-01 , 2.9381E-01 , 4.2778E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  450, 5.00, 1.73600E-01/                       CLDBDR
      DATA(RFL10(I,1,4),I=1,45)                                           CLDBDR
     X / 3.0171E-02 , 4.0968E-02 , 5.2498E-02 , 6.0945E-02 , 7.3305E-02, CLDBDR
     X   3.0411E-02 , 4.0016E-02 , 5.0964E-02 , 6.1708E-02 , 8.5349E-02, CLDBDR
     X   3.1124E-02 , 4.1387E-02 , 5.2687E-02 , 6.2451E-02 , 8.1067E-02, CLDBDR
     X   3.4008E-02 , 4.6370E-02 , 5.8683E-02 , 6.5175E-02 , 7.0335E-02, CLDBDR
     X   4.1566E-02 , 5.8808E-02 , 7.8585E-02 , 9.5280E-02 , 1.2007E-01, CLDBDR
     X   4.3259E-02 , 7.0946E-02 , 1.0915E-01 , 1.5036E-01 , 2.0957E-01, CLDBDR
     X   5.8935E-02 , 1.0602E-01 , 1.8261E-01 , 2.9294E-01 , 5.1499E-01, CLDBDR
     X   5.8149E-02 , 1.3646E-01 , 3.0546E-01 , 6.3216E-01 , 1.4125E+00, CLDBDR
     X   6.0197E-02 , 1.6701E-01 , 4.5542E-01 , 1.2160E+00 , 3.9358E+00/ CLDBDR
      DO 20 I = 1,4                                                       CLDBDR
      ITHIN = I                                                           CLDBDR
      IF(CTHIN .GT. TCTHIN(I)) GO TO 30                                   CLDBDR
   20 CONTINUE                                                            CLDBDR
   30 DO 40 I = 1,5                                                       CLDBDR
      ITHOUT = I                                                          CLDBDR
      IF(CTHOUT .GT. TCTHOUT(I)) GO TO 50                                 CLDBDR
   40 CONTINUE                                                            CLDBDR
   50 DO 60 I = 1,9                                                       CLDBDR
      IPHOUT = I                                                          CLDBDR
      IF( CPHOUT .LT. TCPHOUT(I)) GO TO 70                                CLDBDR
   60 CONTINUE                                                            CLDBDR
   70 CONTINUE                                                            CLDBDR
      DO 80 I = 2,10                                                      CLDBDR
      ILAM = I - 1                                                        CLDBDR
      IF(ALAM .LT. ALAMT(I)) GO TO 90                                     CLDBDR
   80 CONTINUE                                                            CLDBDR
   90 CONTINUE                                                            CLDBDR
      XLAM = (ALAM - ALAMT(ILAM)) / (ALAMT(ILAM+1) - ALAMT(ILAM))         CLDBDR
      GO TO(110,120,130,140,150,160,170,180,190 ) ILAM                    CLDBDR
  110 CLDBDR = RFL1(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL2(ITHOUT,IPHOUT,ITHIN) - RFL1(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  120 CLDBDR = RFL2(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL3(ITHOUT,IPHOUT,ITHIN) - RFL2(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  130 CLDBDR = RFL3(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL4(ITHOUT,IPHOUT,ITHIN) - RFL3(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  140 CLDBDR = RFL4(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL5(ITHOUT,IPHOUT,ITHIN) - RFL4(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  150 CLDBDR = RFL5(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL6(ITHOUT,IPHOUT,ITHIN) - RFL5(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  160 CLDBDR = RFL6(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL7(ITHOUT,IPHOUT,ITHIN) - RFL6(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  170 CLDBDR = RFL7(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL8(ITHOUT,IPHOUT,ITHIN) - RFL7(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  180 CLDBDR = RFL8(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL9(ITHOUT,IPHOUT,ITHIN) - RFL8(ITHOUT,IPHOUT,ITHIN)) *XLAM   CLDBDR
      RETURN                                                              CLDBDR
  190 CLDBDR = RFL9(ITHOUT,IPHOUT,ITHIN)                                  CLDBDR
    1  + (RFL10(ITHOUT,IPHOUT,ITHIN) - RFL9(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                              CLDBDR
      END                                                                 CLDBDR
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```
CLJ      CLOUDA(K) = LONGEST SEMI-AXIS OF CLOUD-K.  ASSUMED TO BE IN   CLDGEOM    59
CLJ                  HORIZONTAL PLANE AND WILL BE IN EAST-WEST         CLDGEOM    60
CLJ                  DIRECTION IF ORIENTATION ANGLE CLDPSI=0.0,  KM    CLDGEOM    61
CLJ      CLOUDB(K) = SEMI-MINOR AXIS IN HORIZONTAL PLANE OF ELLIPSOIDAL CLDGEOM   62
CLJ                  CLOUD-K,  KM                                      CLDGEOM    63
CLJ      CLOUDC(K) = SEMI-MINOR AXIS IN VERTICAL DIRECTION OF          CLDGEOM    64
CLJ                  ELLIPSOIDAL CLOUD-K,  KM                          CLDGEOM    65
CLJ    PARAMS COMMON                                                   CLDGEOM    66
CLJ            RTD = CONVERSION FACTOR FROM RADIANS TO DEGREES         CLDGEOM    67
CLJ            DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS         CLDGEOM    68
CLJ  OUTPUT PARAMETERS                                                 CLDGEOM    69
CLJ    CDCORD COMMON                                                   CLDGEOM    70
CLJ       CTH(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF A    CLDGEOM    71
CLJ                  BOUNDARY OF THE I-TH POLAR SET OF SURFACE FACETS  CLDGEOM    72
CLJ                  FOR THE PRINCIPAL OCTANT OF THE ELLIPSOIDAL       CLDGEOM    73
CLJ                  CLOUD-K,  RADIANS      I=1,5      K=1,20          CLDGEOM    74
CLJ       CPH(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF A CLDGEOM   75
CLJ                  BOUNDARY OF THE J-TH AZIMUTHAL SET OF SURFACE     CLDGEOM    76
CLJ                  FACETS FOR THE PRINCIPAL OCTANT OF THE ELLIPSOIDAL CLDGEOM   77
CLJ                  CLOUD-K,  RADIANS      J=1,5      K=1,20          CLDGEOM    78
CLJ    CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE  CLDGEOM    79
CLJ                  CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR CLDGEOM   80
CLJ                  ELLIPSOIDAL CLOUD-K,  DEGREES     I=1,8    K=1,20 CLDGEOM    81
CLJ   CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF  CLDGEOM    82
CLJ                  THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE   CLDGEOM    83
CLJ                  FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES          CLDGEOM    84
CLJ                          J=1,16    K=1,20                          CLDGEOM    85
CLJ   CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF   CLDGEOM    86
CLJ                  SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM        CLDGEOM    87
CLJ                      I=1,4      J=1,4      K=1,20                  CLDGEOM    88
CLJ                  (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) CLDGEOM   89
CLJ   CAREA(I,J,K) = AREA OF SURFACE FACET I,J IN PRINCIPAL OCTANT OF  CLDGEOM    90
CLJ                  ELLIPSOIDAL CLOUD-K,  KM**2   I=1,4  J=1,4  K=1,20 CLDGEOM   91
CLJ         ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        CLDGEOM    92
CLJ                  HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      CLDGEOM    93
CLJ         BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        CLDGEOM    94
CLJ                  HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      CLDGEOM    95
CLJ         CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        CLDGEOM    96
CLJ                  VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    CLDGEOM    97
CLJ                                                                    CLDGEOM    98
C                                                                      CLDGEOM    99
      COMMON/CLOUD/ NCLOUD,                                            CLOUD       2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD       3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                             CLOUD       4
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                 CDCORD      2
     1              XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD      3
     X  , ASQ(20),BSQ(20),CSQ(20)                                      CDCORD      4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)        CDCORD      5
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                           PARAMS      2
C        MAPPING OF AREAS AND RBARS                                    CLDGEOM   103
C        FIRST QUAD SYMMETRIC AREA-- ALSO GOOD FOR THE THETA INDEX     CLDGEOM   104
CLJ      FUNCTION IPRIME, CALLED WITH A NUMBER IN THE FIRST COLUMN,    CLDGEOM   105
CLJ      SHOULD RETURN THE PAIRED NUMBER IN THE SECOND COLUMN.         CLDGEOM   106
C         1  -  1                                                      CLDGEOM   107
C         2  -  2                                                      CLDGEOM   108
C         3  -  3                                                      CLDGEOM   109
C         4  -  4                                                      CLDGEOM   110
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C         5  -  4                                                        CLDGEOM   111
C         6  -  3                                                        CLDGEOM   112
C         7  -  2                                                        CLDGEOM   113
C         8  -  1                                                        CLDGEOM   114
C         9  -  1                                                        CLDGEOM   115
C        10  -  2                                                        CLDGEOM   116
C        11  -  3                                                        CLDGEOM   117
C        12  -  4                                                        CLDGEOM   118
C        13  -  4                                                        CLDGEOM   119
C        14  -  3                                                        CLDGEOM   120
C        15  -  2                                                        CLDGEOM   121
C        16  -  1                                                        CLDGEOM   122
C     THE AREAS, RBAR TO THE MIDPOINTS,THBAR AND PHIBAR ARE EVALUATED   CLDGEOM   123
C         FOR EACH OF THE CLOUDS                                         CLDGEOM   124
C                                                                        CLDGEOM   125
      DIMENSION G(21)                                                    CLDGEOM   126
      DATA XINT,NINT,NINTM2/20.,21,19/                                   CLDGEOM   127
C                                                                        CLDGEOM   128
C         STATEMENTS TO DETERMINE THETA AND PHI IN THE CLOUD SYSTEM      CLDGEOM   129
C                                                                        CLDGEOM   130
      ALFA = 0.80                                                        CLDGEOM   131
      BETA = 0.80                                                        CLDGEOM   132
      DO 1000 K=1,NCLOUD                                                 CLDGEOM   133
      ASQ(K)= CLOUDA(K)**2                                               CLDGEOM   134
      BSQ(K)= CLOUDB(K)**2                                               CLDGEOM   135
      CSQ(K)= CLOUDC(K)**2                                               CLDGEOM   136
      PIBY2 = PI/2.                                                      CLDGEOM   137
      CBYA = CLOUDC(K)/CLOUDA(K)                                         CLDGEOM   138
      BBYA = CLOUDB(K)/CLOUDA(K)                                         CLDGEOM   139
      DTH = PIBY2/(1.+CBYA**ALFA + CBYA**(2.*ALFA) + CBYA**(3.*ALFA))    CLDGEOM   140
      DPH = PIBY2/(1.+BBYA**BETA + BBYA**(2.*BETA) + BBYA**(3.*BETA))    CLDGEOM   141
      CTH(1,K) = 0.0                                                     CLDGEOM   142
      CTH(2,K) = DTH                                                     CLDGEOM   143
      CTH(3,K) = DTH*(1.0 + CBYA**ALFA)                                  CLDGEOM   144
      CTH(4,K) = PIBY2 - DTH*CBYA**(3.*ALFA)                             CLDGEOM   145
      CTH(5,K) = PIBY2                                                   CLDGEOM   146
      CPH(1,K) = 0.0                                                     CLDGEOM   147
      CPH(2,K) = DPH*BBYA**(3.*BETA)                                     CLDGEOM   148
      CPH(3,K) = PIBY2 - DPH*(1.0 + BBYA**BETA)                          CLDGEOM   149
      CPH(4,K) = PIBY2 - DPH                                             CLDGEOM   150
      CPH(5,K) = PIBY2                                                   CLDGEOM   151
      CPHIBAR(1,K) = 0.                                                  CLDGEOM   152
      CTHBAR(1,K) = 0.                                                   CLDGEOM   153
      DO 10 I = 1,4                                                      CLDGEOM   154
      CPHIBAR(I,K) = (CPH (I,K) + CPH (I+1,K)) / 2.                      CLDGEOM   155
      CTHBAR(I,K) =  (CTH (I,K) + CTH (I+1,K)) / 2.                      CLDGEOM   156
      CTHBAR(9-I,K) = PI - CTHBAR(I,K)                                   CLDGEOM   157
      CPHIBAR(9-I,K) = PI - CPHIBAR(I,K)                                 CLDGEOM   158
      CPHIBAR(17-I,K) = 2.*PI - CPHIBAR(I,K)                             CLDGEOM   159
        CPHIBAR(8+I,K) = PI + CPHIBAR(I,K)                               CLDGEOM   160
   10 CONTINUE                                                           CLDGEOM   161
      DO 12 I = 1,16                                                     CLDGEOM   162
      CPHIBAR(I,K) = CPHIBAR(I,K) * RTD                                  CLDGEOM   163
      IF(I .GT. 8) GO TO 12                                              CLDGEOM   164
      CTHBAR(I,K) = CTHBAR(I,K) * RTD                                    CLDGEOM   165
   12 CONTINUE                                                           CLDGEOM   166
      DO 15 I = 1,4                                                      CLDGEOM   167
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      A21 = SIN(DTR*CPHIBAR(I,K))**2                                    CLDGEON  168
      A12 = 1.0-A21                                                     CLDGEON  169
      DO 15 J = 1,4                                                     CLDGEON  170
      A31 = COS(DTR*CTHBAR (J,K) )**2                                   CLDGEON  171
      A11 = 1.0-A31                                                     CLDGEON  172
      CRBAR(J,I,K) = 1. / SQRT(A11*A12 / ASQ(K)                         CLDGEON  173
     X + A11*A21/BSQ(K) + A31/CSQ(K) )                                  CLDGEON  174
   15 CONTINUE                                                          CLDGEON  175
C                                                                       CLDGEON  176
C      EVALUATE AREA                                                    CLDGEON  177
      SURFAC = 0.                                                       CLDGEON  178
      THETAM = CTH(1,K)                                                 CLDGEON  179
      DO 390 I=1,4                                                      CLDGEON  180
      DTHETA = (CTH(I+1,K)-THETAM)/XINT                                 CLDGEON  181
      PHIM = CPH(1,K)                                                   CLDGEON  182
      DO 380 J=1,4                                                      CLDGEON  183
      CAREA(I,J,K) = 0.                                                 CLDGEON  184
      DPHI = (CPH(J+1,K)-PHIM)/XINT                                     CLDGEON  185
      DA = DTHETA * DPHI / 9.0                                          CLDGEON  186
      DO 360 II=1,NINT                                                  CLDGEON  187
      G(II)=0.0                                                         CLDGEON  188
      XII=II-1                                                          CLDGEON  189
      TII=THETAM+XII*DTHETA                                             CLDGEON  190
      DO 350 JJ=1,NINTM2,2                                              CLDGEON  191
      YJJ=JJ-1                                                          CLDGEON  192
      PJJ1=PHIM+YJJ*DPHI                                                CLDGEON  193
      PJJ2=PJJ1+DPHI                                                    CLDGEON  194
      PJJ3=PJJ2+DPHI                                                    CLDGEON  195
      G(II)=G(II)+DSURF(TII,PJJ1,K)+4.*DSURF(TII,PJJ2,K)+               CLDGEON  196
     1   DSURF(TII,PJJ3,K)                                              CLDGEON  197
  350 CONTINUE                                                          CLDGEON  198
  360 CONTINUE                                                          CLDGEON  199
      DO 370 II=1,NINTM2,2                                              CLDGEON  200
      CAREA(I,J,K) = CAREA(I,J,K) + DA*(G(II) + 4.*G(II+1) + G(II+2))   CLDGEON  201
  370 CONTINUE                                                          CLDGEON  202
      SURFAC = SURFAC + CAREA(I,J,K)                                    CLDGEON  203
      PHIM = CPH(J+1,K)                                                 CLDGEON  204
  380 CONTINUE                                                          CLDGEON  205
      THETAM = CTH(I+1,K)                                               CLDGEON  206
  390 CONTINUE                                                          CLDGEON  207
 1000 CONTINUE                                                          CLDGEON  208
      RETURN                                                            CLDGEON  209
      END                                                               CLDGEON  210
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      SUBROUTINE CLDWT(ALAM,ANG)                                        CLDWT      2
      COMMON /CONFIG/CTYPL(8),CTYPM(4),CTYPH(5),CFLAG,C1,C2             CONFIG     2
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)               CLDFREQ    2
      COMMON/CLDWT/IDX,WT(161),TRANS(161),EMISS(161)                    CLDWGT     2
      DIMENSION ALX(20),P(20),W(5)                                      CLDWT      6
      EQUIVALENCE(ALX,P)                                                CLDWT      7
      DIMENSION TYPEL(8),TYPEM(4),TYPEH(5)                              CLDWT      8
      DIMENSION ICC(5)                                                  CLDWT      9
      INTEGER H1,H2,HH,CC,C1,C2                                         CLDWT     10
      INTEGER CFLAG                                                     CLDWT     11
CCC                                                                     CLDWT     12
CLJ   SUBROUTINE CLDWT, FOR GIVEN SOURCE AND DETECTOR LOCATIONS,        CLDWT     13
CLJ   COMPUTES THREE ARRAYS (TRANS, EMISS, AND WT), EACH WITH IDX       CLDWT     14
CLJ   MEMBERS (NORMALLY 160).  THE TRANS AND EMISS ARRAYS ARE,          CLDWT     15
CLJ   RESPECTIVELY, (1) THE DISTRIBUTION OF IRRADIANCE-TO-RADIANCE      CLDWT     16
CLJ   TRANSFER COEFFICIENTS (1/SR) AT THE 12-KM ALTITUDE TRANSFER POINT CLDWT     17
CLJ   AND (2) THE DISTRIBUTION OF (ATTENUATED) SPECTRAL RADIANCES       CLDWT     18
CLJ   (WATTS/(KM**2 SR MICRON)) AT 12-KM ALTITUDE AND DIRECTED TOWARD   CLDWT     19
CLJ   THE DETECTOR.  THE WT ARRAY IS THE SET OF WEIGHTS ASSOCIATED WITH CLDWT     20
CLJ   THE SET OF STATISTICAL CLOUD CONFIGURATIONS, INFLUENCED BY        CLDWT     21
CLJ   CLOUD-COVERAGE FRACTIONS AND CLOUD-FREE LINE-OF-SIGHTS FROM THE   CLDWT     22
CLJ   DETECTOR.                                                         CLDWT     23
CCC                                                                     CLDWT     24
CLJ   INPUT VARIABLES                                                   CLDWT     25
CLJ      ARGUMENT LIST                                                  CLDWT     26
CLJ            ALAM = WAVELENGTH,  MICRONS                              CLDWT     27
CLJ             ANG = ZENITH ANGLE OF THE DETECTOR MEASURED AT THE INTER- CLDWT   28
CLJ                   SECTION POINT OF THE DETECTOR LOS WITH THE EARTH'S CLDWT    29
CLJ                   SURFACE,  DEGREES                                 CLDWT     30
CLJ      CLDFREQ COMMON                                                 CLDWT     31
CLJ            DEFINITIONS OF THE FOLLOWING THREE QUANTITIES ARE IN     CLDWT     32
CLJ            THE BLOCK DATA ROUTINE.  KMODEL, CCOVER(ICC,KMODEL),     CLDWT     33
CLJ            AND CFREQ(KCLOUD,ICC,KMODEL)                             CLDWT     34
CLJ   OUTPUT VARIABLES                                                  CLDWT     35
CLJ      CLDWT COMMON                                                   CLDWT     36
CLJ             IDX = AS AN OUTPUT QUANTITY, IDX IS ONE PLUS THE TOTAL  CLDWT     37
CLJ                   NUMBER OF CLOUD CONFIGURATIONS, WHICH IS 1+159=160 CLDWT    38
CLJ                   FOR KMODEL=1,10.  FOR KMODEL=11, THE USER SUPPLIES CLDWT    39
CLJ                   STATISTICAL CLOUD DATA AND IDX MAY BE DIFFERENT.  CLDWT     40
CLJ                   HOWEVER, DIMENSION STATEMENTS CURRENTLY RESTRICT  CLDWT     41
CLJ                   IDX FROM BEING LARGER THAN 160.                   CLDWT     42
CLJ           WT(I) = FOR ANY OF THE 10 LOCATION-SEASON AVERAGED        CLDWT     43
CLJ                   STATISTICAL CLOUD MODELS (KMODEL=1,10), WT(I) IS  CLDWT     44
CLJ                   THE PROBABILITY THAT (A) THE CLOUD-CONFIGURATION  CLDWT     45
CLJ                   SET INDICATED BY THE INDEX I OCCURS AND (B) THE   CLDWT     46
CLJ                   DETECTOR LOS AT ZENITH ANGLE ANG INTERSECTS THE   CLDWT     47
CLJ                   CLOUD-CONFIGURATION SET.  THE TOTAL PROBABILITY OF CLDWT    48
CLJ                   THE DETECTOR LOS INTERSECTING CLOUDS IS SUM(WT(I)) CLDWT    49
CLJ                   (I=1,IDX-1).  THE PROBABILITY THAT THE LOS DOES NOT CLDWT   50
CLJ                   INTERSECT THE CLOUDS BUT SEES THROUGH GAPS IN THE CLDWT     51
CLJ                   CLOUDS IS WTOLD(IDX).  THE PROBABILITY OF THE LOS CLDWT     52
CLJ                   SEEING THE GROUND FOR A 0.0 CLOUD-COVERAGE FRACTION CLDWT   53
CLJ                   IS CCOVER(1,KMODEL) IN THE CODE, ALTHOUGH STRICTLY CLDWT    54
CLJ                   THIS QUANTITY SHOULD BE MULTIPLIED BY CFLOS(0,ANG). CLDWT   55
CLJ                   THE PROBABILITY OF THE LOS SEEING THE GROUND EITHER CLDWT   56
CLJ                   WITH OR WITHOUT CLOUDS BEING PRESENT IS WTNEW(IDX)= CLDWT   57
CLJ                   WTOLD(IDX)+CCOVER(1,KMODEL).  THE PROBABILITY OF  CLDWT     58
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      CLJ                  SEEING EITHER CLOUDS OR THE GROUND (WITH OR WITHOUT  CLDWT
      CLJ                  CLOUDS BEING PRESENT) IS SUM(WT(I)), (I=1,IDX-1) +   CLDWT
      CLJ                  WTNEW(IDX) = 1.0                                    CLDWT
      CLJ       TRANS(I) = THE (ATTENUATED) IRRADIANCE-TO-RADIANCE TRANSFER    CLDWT
      CLJ                  COEFFICIENT AT THE 12-KM ALTITUDE TRANSFER POINT    CLDWT
      CLJ                  FOR CLOUD-CONFIGURATION SET I,  1/SR                CLDWT
      CLJ                  (MORE INFORMATION IS GIVEN IN FUNCTION TRANSF.)     CLDWT
      CLJ       EMISS(I) = THE (ATTENUATED) SPECTRAL RADIANCE AT 12-KM         CLDWT
      CLJ                  ALTITUDE FOR RADIATION EMITTED AT ZENITH ANGLE ANG  CLDWT
      CLJ                  FROM THE HIGHEST CLOUD-TOP IN CLOUD-CONFIGURATION   CLDWT
      CLJ                  SET I,  WATTS/(KM**2 SR MICRON)                     CLDWT
      CLJ                                                                      CLDWT
      CLJ           FOR  WT, TRANS, AND EMISS  I=1,IDX-1                        CLDWT
      CCC                                                                      CLDWT
            DATA TYPEL  /3HCU1,3HCU2,3HCU3,3HSC ,3HST ,3HCB1,3HNS ,3HCLR /     CLDWT
            DATA TYPEM  /3HAC ,3HAS1,3HCB2,3HCLR                        /     CLDWT
            DATA TYPEH  /3HCB3,3HAS2,3HCI ,3HCS ,3HCLR                  /     CLDWT
            DATA L1,L2,M1,M2,H1,H2,C1,C2 /1,7,1,3,1,4,2,5     /               CLDWT
            DATA CTYPL / 3HCU1,3HCU2,3HCU3,3HSC ,3HST ,3HCB1,3HNS ,3HCLR /     CLDWT
            DATA CTYPM / 3HAC ,3HAS1,3HCB2,3HCLR      /                        CLDWT
            DATA CTYPH / 3HCB3,3HAS2,3HCI ,3HCS ,3HCLR        /                CLDWT
            DATA ICC / 1,4,6,9,11 /                                            CLDWT
            DATA CFLAG / 1 /                                                   CLDWT
      C                                                                        CLDWT
      C      INPUTS AND OUTPUTS                                                CLDWT
      C        ALAM      WAVELENGTH IN MICROMETERS                             CLDWT
      C        WT        PROBABILITY FN  160 (OR OR FEWER) NUMBERS             CLDWT
      C        TRANS     TRANSFER COEF (SR-1)                                  CLDWT
      C        EMISS     THERMAL EMISSION FROM CLOUD (RADIANCE)                CLDWT
      C        ANG       LINE OF SIGHT EXIT ANGLE                              CLDWT
      C                                                                        CLDWT
            DO 10 I = 1,160                                                    CLDWT
            WT(I) = 0.                                                         CLDWT
            EMISS(I) = 0.                                                      CLDWT
         10 TRANS(I) = 0.0                                                     CLDWT
      C                                                                        CLDWT
            DO 500 II = C1,C2                                                  CLDWT
            CC = II                                                            CLDWT
            IDX = 0                                                            CLDWT
            CFLOS = CFLOSF(ICC(II) , ANG)                                      CLDWT
            W(CC) = CCOVER(CC,KMODEL)                                          CLDWT
            NT = 17                                                            CLDWT
            DO 71 J = 1,NT                                                     CLDWT
         71 P(J) = CFREQ(J,CC-1,KMODEL)                                        CLDWT
            TOTL=ALX(1) + ALX(2) + ALX(3) + ALX(4) + ALX(5) + ALX(6) + ALX(7)  CLDWT
            TOTM = ALX(8) + ALX(9) + ALX(10)                                   CLDWT
            TOTH = ALX(11) + ALX(12) + ALX(13) + ALX(14)                       CLDWT
            IF( TOTL .EQ. 0 ) TOTL = 1.                                        CLDWT
            IF( TOTM .EQ. 0 ) TOTM = 1.                                        CLDWT
            IF( TOTH .EQ. 0 ) TOTH = 1.                                        CLDWT
      C    1 LAYER                                                             CLDWT
              MM = 4                                                           CLDWT
            HH = 5                                                             CLDWT
            DO 101 LL = L1,L2                                                  CLDWT
            IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 101          CLDWT
            IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 101          CLDWT
            IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 101          CLDWT
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      PIJKL = P(LL) * P(15) * W(CC)                                  CLDWT
      IDX = IDX + 1                                                  CLDWT
      IF(TRANS(IDX) .NE. 0.) GO TO 1101                              CLDWT
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                             CLDWT
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                             CLDWT
 1101 CONTINUE                                                       CLDWT
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                         CLDWT
       WT(160) = WT(160) + PIJKL * CFLOS                             CLDWT
  101 CONTINUE                                                       CLDWT
        LL = 8                                                       CLDWT
      HH = 5                                                         CLDWT
      DO 102 MM = M1,M2                                              CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 102      CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 102      CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 102      CLDWT
      PIJKL = P(MM+7) * P(15) * W(CC)                                CLDWT
      IDX = IDX + 1                                                  CLDWT
      IF(TRANS(IDX) .NE. 0.) GO TO 1102                              CLDWT
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                             CLDWT
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                             CLDWT
 1102 CONTINUE                                                       CLDWT
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                         CLDWT
       WT(160) = WT(160) + PIJKL * CFLOS                             CLDWT
  102 CONTINUE                                                       CLDWT
      LL = 8                                                         CLDWT
      MM = 4                                                         CLDWT
      DO 103 HH = H1,H2                                              CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 103      CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 103      CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 103      CLDWT
      PIJKL = P(HH+10)*P(15) * W(CC)                                 CLDWT
      IDX = IDX + 1                                                  CLDWT
      IF(TRANS(IDX) .NE. 0.) GO TO 1103                              CLDWT
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                             CLDWT
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                             CLDWT
 1103 CONTINUE                                                       CLDWT
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                         CLDWT
       WT(160) = WT(160) + PIJKL * CFLOS                             CLDWT
  103 CONTINUE                                                       CLDWT
C   2- LAYER                                                         CLDWT
      DEN = TOTL * TOTM + TOTL * TOTH + TOTM * TOTH                  CLDWT
C     2 LAYER CASE   LL AND MM                                       CLDWT
      HH = 5                                                         CLDWT
      DO 200 LL = L1,L2                                              CLDWT
      DO 200 MM = M1,M2                                              CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 200      CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 200      CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 200      CLDWT
      PL = ALX(LL)/ TOTL                                             CLDWT
      PM = ALX(MM+7) / TOTM                                          CLDWT
      PIJKL = PL*PM*TOTL*TOTM/DEN*W(CC) * P(16)                      CLDWT
      IDX = IDX + 1                                                  CLDWT
      IF(TRANS(IDX) .NE. 0.) GO TO 1201                              CLDWT
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                             CLDWT
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                             CLDWT
 1201 CONTINUE                                                       CLDWT
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                         CLDWT
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      WT(160) = WT(160) + PIJKL * CFLOS                                 CLDWT    173
  200 CONTINUE                                                          CLDWT    174
C   2 LAYER CASE LL AND HH                                              CLDWT    175
      MM = 4                                                            CLDWT    176
      DO 201 LL = L1,L2                                                 CLDWT    177
      DO 201 HH = H1,H2                                                 CLDWT    178
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 201         CLDWT    179
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 201         CLDWT    180
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 201         CLDWT    181
      PL = ALX(LL)/ TOTL                                                CLDWT    182
      PH = ALX(HH+10) / TOTH                                            CLDWT    183
      PIJKL = PL * PH * TOTL * TOTH / DEN * W(CC) * P(16)               CLDWT    184
      IDX = IDX + 1                                                     CLDWT    185
      IF(TRANS(IDX) .NE. 0.) GO TO 1202                                 CLDWT    186
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    187
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    188
 1202 CONTINUE                                                          CLDWT    189
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    190
       WT(160) = WT(160) + PIJKL * CFLOS                                CLDWT    191
  201 CONTINUE                                                          CLDWT    192
C   2 LAYER CASE MM AND HH                                              CLDWT    193
      LL = 8                                                            CLDWT    194
      DO 202 MM = M1,M2                                                 CLDWT    195
      DO 202 HH = H1,H2                                                 CLDWT    196
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 202         CLDWT    197
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 202         CLDWT    198
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 202         CLDWT    199
      PM = ALX(MM+7) / TOTM                                             CLDWT    200
      PH = ALX(HH+10) / TOTH                                            CLDWT    201
      PIJKL = PM * PH * TOTM * TOTH / DEN * W(CC) * P(16)               CLDWT    202
      IDX = IDX + 1                                                     CLDWT    203
      IF(TRANS(IDX) .NE. 0.) GO TO 1203                                 CLDWT    204
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    205
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    206
 1203 CONTINUE                                                          CLDWT    207
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    208
       WT(160) = WT(160) + PIJKL * CFLOS                                CLDWT    209
  202 CONTINUE                                                          CLDWT    210
C   3 LAYER CASE                                                        CLDWT    211
      DO 300 LL = L1,L2                                                 CLDWT    212
      DO 300 MM = M1,M2                                                 CLDWT    213
      DO 300 HH = H1,H2                                                 CLDWT    214
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 300         CLDWT    215
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 300         CLDWT    216
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 300         CLDWT    217
      PL = ALX(LL)/ TOTL                                                CLDWT    218
      PM = ALX(MM+7) / TOTM                                             CLDWT    219
      PH = ALX(HH+10) / TOTH                                            CLDWT    220
      PIJKL = PL * PM * PH * W(CC) * P(17)                              CLDWT    221
      IDX = IDX + 1                                                     CLDWT    222
      IF(TRANS(IDX) .NE. 0.) GO TO 1301                                 CLDWT    223
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    224
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    225
 1301 CONTINUE                                                          CLDWT    226
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    227
       WT(160) = WT(160) + PIJKL * CFLOS                                CLDWT    228
  300 CONTINUE                                                          CLDWT    229
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  500 CONTINUE                                                 CLDWT   230
C         ADD IN CLEAR SKY                                     CLDWT   231
      WT(160) = WT(160) + CCOVER(1,KMODEL)                     CLDWT   232
      IDX = IDX + 1                                            CLDWT   233
      WT(IDX) = WT(160)                                        CLDWT   234
CLJ       TRANS(IDX) AND EMISS(IDX) WILL BE COMPUTED           CLDWT   235
CLJ       IN SUBROUTINE SCLOUD.                                CLDWT   236
 1112 RETURN                                                   CLDWT   237
      END                                                      CLDWT   238
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          SUBROUTINE CLOUDO(MODE)                                            CLOUDO    2
          COMMON/CLOUD/ NCLOUD,                                              CLOUD     2
         1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),        CLOUD     3
         2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                               CLOUD     4
          COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                             PARAMS    2
          COMMON /CONFIG/CTYPL(8),CTYPM(4),CTYPH(5),CFLAG,C1,C2              CONFIG    2
          COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)                CLDFREQ   2
CCC                                                                          CLOUDO    7
CLJ       SUBROUTINE CLOUDO FIRST READS A FLAG (MODE) INDICATING BY A VALUE  CLOUDO    8
CLJ       OF 0 OR 1 WHETHER THE DETERMINISTIC- OR STATISTICAL-CLOUD SUB-     CLOUDO    9
CLJ       MODEL IS DESIRED.  THE ROUTINE THEN READS CLOUD DATA APPROPRIATE   CLOUDO   10
CLJ       TO THE INDICATED SUBMODEL AND MAKES THEM AVAILABLE TO THE          CLOUDO   11
CLJ       APPROPRIATE ROUTINES.                                              CLOUDO   12
CLJ       FOR THE DETERMINISTIC SUBMODEL (MODE=0), THE NUMBER OF CLOUDS,     CLOUDO   13
CLJ       THEIR LOCATIONS, TYPES, SIZES, AND (AZIMUTHAL) ORIENTATIONS ARE    CLOUDO   14
CLJ       READ AND OUTPUTTED THROUGH CLOUD COMMON.                           CLOUDO   15
CLJ       FOR THE STATISTICAL SUBMODEL (MODE=1), THE ROUTINE READS AN INDEX  CLOUDO   16
CLJ       KMODEL WHICH SELECTS DATA FROM THAT IN THE CODE OR ALLOWS THE      CLOUDO   17
CLJ       USER TO INPUT HIS OWN DATA.  OTHER FLAGS ARE READ WHICH ALLOW      CLOUDO   18
CLJ       SELECTED PORTIONS OF THE PROVUDED DATA TO BE OVERRIDDEN.  THESE    CLOUDO   19
CLJ       USER-PROVIDED DATA ARE OUTPUTTED THROUGH CLDFREQ AND CONFIG        CLOUDO   20
CLJ       COMMONS AND OVERRIDE DATA IN BLOCK DATA.                           CLOUDO   21
CCC                                                                          CLOUDO   22
CLJ       INPUT VARIABLES                                                    CLOUDO   23
CLJ          READ IN                                                         CLOUDO   24
CLJ                MODE = FLAG FOR DETERMINISTIC- OR STATISTICAL-CLOUD       CLOUDO   25
CLJ                       SUBMODEL                                           CLOUDO   26
CLJ                     = 0  FOR DETERMINISTIC-CLOUD SUBMODEL                CLOUDO   27
CLJ                     = 1  FOR STATISTICAL-CLOUD SUBMODEL                  CLOUDO   28
CLJ          FOR MODE=0 READ...    (DETERMINISTIC SUBMODEL)                  CLOUDO   29
CLJ             NCLOUD    = NUMBER OF CLOUDS                                 CLOUDO   30
CLJ          FOR I=1,NCLOUD...                                               CLOUDO   31
CLJ             KCLOUD(I) = CLOUD-TYPE INDEX,  1,2,...14                     CLOUDO   32
CLJ             HCLOUD(I) = ALTITUDE OF CLOUD-I CENTER ABOVE THE             CLOUDO   33
CLJ                         SURFACE,  KM                                     CLOUDO   34
CLJ             THETCD(I) = COLATITUDE OF CLOUD-I,  DEGREES                  CLOUDO   35
CLJ              PHICD(I) = EAST LONGITUDE OF CLOUD-I,  DEGREES              CLOUDO   36
CLJ             CLOUDA(I) = PRINCIPAL SEMIAXIS OF ELLIPSOIDAL CLOUD-I        CLOUDO   37
CLJ                         IN HORIZONTAL DIRECTION,  KM                     CLOUDO   38
CLJ             CLOUDB(I) = PRINCIPAL SEMIAXIS OF ELLIPSOIDAL CLOUD-I        CLOUDO   39
CLJ                         IN HORZONTAL DIRECTION,  KM                      CLOUDO   40
CLJ             CLOUDC(I) = PRINCIPAL SEMIAXIS OF ELLIPSOIDAL CLOUD-I        CLOUDO   41
CLJ                         IN VERTICAL DIRECTION,  KM                       CLOUDO   42
CLJ             CLDPSI(I) = AZIMUTHAL ANGLE, MEASURED COUNTERCLOCKWISE       CLOUDO   43
CLJ                         LOOKING DOWN, ORIENTING CLOUD ABOUT (VERTICAL)   CLOUDO   44
CLJ                         Z-AXIS.  CLOUDS ARE NORMALLY ORIENTED WITH       CLOUDO   45
CLJ                         (+A)-AXIS EASTWARD (PSI=0.),  DEGREES            CLOUDO   46
CLJ          FOR MODE=1 READ...    ( STATISTICAL  SUBMODEL)                  CLOUDO   47
CLJ             KMODEL = FLAG CONTROLLING THE READING OF USER-SUPPLIED       CLOUDO   48
CLJ                      STATISTICAL CLOUD DATA (FURTHER DESCRIPTION IN      CLOUDO   49
CLJ                      BLOCK DATA)                                         CLOUDO   50
CLJ                    - 1,10  CODE USES DATA IN BLOCK DATA                  CLOUDO   51
CLJ                    - 11      USER MUST READ IN FOLLOWING QUANTITIES...   CLOUDO   52
CLJ                              CCOVER(ICC,11)  ICC=1,5                     CLOUDO   53
CLJ                              CFREQ(K,ICC-1,11)  K=1,17   ICC=2,5         CLOUDO   54
CLJ                              (DEFINITIONS IN BLOCK DATA)                 CLOUDO   55
CLJ             KCOVER = FLAG CONTROLLING THE READING OF OVERRIDE DATA       CLOUDO   56
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CLJ           FOR CCOVER(ICC,KMODEL),    ICC=1,5                        CLOUD0    57
CLJ                - 0  DO NOT READ OVERRIDE DATA                       CLOUD0    58
CLJ                - 1  DO READ OVERRIDE DATA                           CLOUD0    59
CLJ        KLAYER = FLAG CONTROLLING THE READING OF OVERRIDE DATA FOR   CLOUD0    60
CLJ                 CFREQ(I,ICC-1,KMODEL),  I=15,17   ICC=2,5           CLOUD0    61
CLJ                - 0  DO NOT READ OVERRIDE DATA                       CLOUD0    62
CLJ                - 1  DO READ OVERRIDE DATA                           CLOUD0    63
CLJ         KTYPL = FLAG CONTROLLING THE READING OF HOLLERITH           CLOUD0    64
CLJ                 ABBREVIATIONS SPECIFYING TYPES OF THE SEVEN         CLOUD0    65
CLJ                 POSSIBLE LOW-ALTITUDE CLOUDS OR CLEAR SKY (CLR)     CLOUD0    66
CLJ                - 0  DO NOT READ DATA                                CLOUD0    67
CLJ                - 1  DO READ DATA                                    CLOUD0    68
CLJ                         CTYPL(1)  =  CU1        CTYPL(5)  =  ST     CLOUD0    69
CLJ                         CTYPL(2)  =  CU2        CTYPL(6)  =  CB1    CLOUD0    70
CLJ                         CTYPL(3)  =  CU3        CTYPL(7)  =  NS     CLOUD0    71
CLJ                         CTYPL(4)  =  SC         CTYPL(8)  =  CLR    CLOUD0    72
CLJ         KTYPM = FLAG CONTROLLING THE READING OF HOLLERITH           CLOUD0    73
CLJ                 ABBREVIATIONS SPECIFYING TYPES OF THE THREE         CLOUD0    74
CLJ                 POSSIBLE MID-ALTITUDE CLOUDS OR CLEAR SKY (CLR)     CLOUD0    75
CLJ                - 0  DO NOT READ DATA                                CLOUD0    76
CLJ                - 1  DO READ DATA                                    CLOUD0    77
CLJ                         CTYPM(1)  =  AC         CTYPM(3)  =  CB2    CLOUD0    78
CLJ                         CTYPM(2)  =  AS1        CTYPM(4)  =  CLR    CLOUD0    79
CLJ         KTYPH = FLAG CONTROLLING THE READING OF HOLLERITH           CLOUD0    80
CLJ                 ABBREVIATIONS SPECIFYING TYPES OF THE FOUR          CLOUD0    81
CLJ                 POSSIBLE HIGH-ALTITUDE CLOUDS OR CLEAR SKY (CLR)    CLOUD0    82
CLJ                - 0  DO NOT READ DATA                                CLOUD0    83
CLJ                - 1  DO READ DATA                                    CLOUD0    84
CLJ                         CTYPH(1)  =  CB3        CTYPH(4)  =  CS     CLOUD0    85
CLJ                         CTYPH(2)  =  AS2        CTYPH(5)  =  CLR    CLOUD0    86
CLJ                         CTYPH(3)  =  CI                             CLOUD0    87
CLJ   OUTPUT VARIABLES                                                  CLOUD0    88
CLJ      ARGUMENT LIST                                                  CLOUD0    89
CLJ            MODE = SEE INPUT FOR DEFINITION                          CLOUD0    90
CLJ      OUTPUT VARIABLES IF MODE=0                                     CLOUD0    91
CLJ      CLOUD COMMON                                                   CLOUD0    92
CLJ             NCLOUD,  FOR I=1,NCLOUD...                              CLOUD0    93
CLJ               HCLOUD(I),  THETCD(I),     PHICD(I),                  CLOUD0    94
CLJ               CLOUDA(I),  CLOUDB(I),  CLOUDC(I)                     CLOUD0    95
CLJ                  (DEFINITIONS GIVEN ABOVE IN INPUT)                 CLOUD0    96
CLJ      OUTPUT VARIABLES IF MODE=1                                     CLOUD0    97
CLJ      CLDFREQ COMMON                                                 CLOUD0    98
CLJ             KMODEL,  IF KMODEL=11...                                CLOUD0    99
CLJ                CCOVER(I,11)  I=1,5                                  CLOUD0   100
CLJ                CFREQ(I,J,11)  I=1,17   J=1,4                        CLOUD0   101
CLJ                      IF KMODEL=1,10... AND IF                       CLOUD0   102
CLJ                KCOVER=1,  CCOVER(I,KMODEL)  I=1,5                   CLOUD0   103
CLJ                KLAYER=1,  CFREQ(I,J,KMODEL)  I=15,17     J=1,4      CLOUD0   104
CLJ      CONFIG COMMON                                                  CLOUD0   105
CLJ                KTYPL=1,  CTYPL(I)  I=1,8                            CLOUD0   106
CLJ                KTYPM=1,  CTYPM(I)  I=1,4                            CLOUD0   107
CLJ                KTYPH=1,  CTYPH(I)  I=1,5                            CLOUD0   108
CCC                                                                     CLOUD0   109
      READ(IN,10) MODE                                                  CLOUD0   110
      IF(MODE .EQ. 1) GO TO 4                                           CLOUD0   111
       READ(IN,10) NCLOUD                                               CLOUD0   112
      WRITE(6,5) MODE,NCLOUD                                            CLOUD0   113
```

```
    6 FORMAT(* MODE=*,I2 /* NCLOUD=*,I2/ )
      DO 5 I=1,NCLOUD
      READ(IN,19)KCLOUD(I),HCLOUD(I),THETCD(I),PHICD(I),CLOUDA(I),
     X CLOUDB(I),CLOUDC(I),CLDPSI(I)
    5 CONTINUE
      WRITE(IOUT,30)
      WRITE(IOUT,50)
      WRITE(IOUT,21)( KCLOUD(I),HCLOUD(I),THETCD(I),PHICD(I),CLOUDA(I),
     X CLOUDB(I),CLOUDC(I),CLDPSI(I),I=1,NCLOUD )
      CALL CLDGEOM
      RETURN
C        READ STATISTICAL CLOUD INFORMATION
    4 CONTINUE
      READ(5,8) KMODEL,KCOVER,KLAYER,KTYPL,KTYPM,KTYPH
    8 FORMAT(6I5)
      WRITE(IOUT,15)  MODE,KMODEL,KCOVER,KLAYER,KTYPL,KTYPM,KTYPH
   15 FORMAT (*0  MODE  =*,I4,4X,*KMODEL =*,I4,4X,*KCOVER =*,I4,4X,
    1 *KLAYER =*,I4/*   KTYPL =*,I4,4X,* KTYPM =*,I4,4X,* KTYPH =*,I4)
      IF(KMODEL .LT. 11) GO TO 17
      READ(5,12) (CCOVER(I,11),I=1,5)
      WRITE(IOUT,16)  (CCOVER(I,11),I=1,5)
      DO 7 J = 1,4
      READ(5,12)(CFREQ (I,J,11),I=1,17)
      WRITE(IOUT,18)  J, (CFREQ(I,J,11),I=1,17)
    7 CONTINUE
   17 CONTINUE
   12 FORMAT(17F4.3)
   13 FORMAT(8A5)
   16 FORMAT (*0    CCOVER(I,11)= *, 5F6.3)
   18 FORMAT (*   CFREQ(I,*,I1,*,11) =*,17F6.3)
C
C        READ MODIFICATIONS TO CLOUD STATISTICS HERE
C        I.E. PARTICULAR CLOUD COVERAGE CATEGORY
C
      IF(KCOVER .GT. 0) READ(5,12) (CCOVER(I,KMODEL),I=1,5)
      IF(KLAYER .GT. 0) READ(5,12) (( CFREQ(I,J,KMODEL),I=15,17),J=1,4)
CLJ        NOTE THAT THE VARIABLES CTYPL(I), CTYPM(I), AND CTYPH(I)
CLJ        MUST BE LEFT-JUSTIFIED IN THE 5-COLUMN FIELDS.
      IF(KTYPL .GT. 0) READ(5,13) (CTYPL(I),I=1,8)
      IF(KTYPM .GT. 0) READ(5,13) (CTYPM(I),I=1,4)
      IF(KTYPH .GT. 0) READ(5,13) (CTYPH(I),I=1,5)
C
C
C
C
C
C
  100   WRITE(IOUT,40)
      RETURN
   10 FORMAT(I10)
   19 FORMAT(I2,E8.3,6E10.4)
   21 FORMAT(5X,I5,1P7E11.4)
   30 FORMAT(20X*OPERATING IN THE DETERMINISTIC MODE *)
   40 FORMAT(20X * OPERATING IN THE STATISTICAL MODE*)
   50 FORMAT(30X* CLOUD DATA*/4X*KCLOUD*3X*ALT*7X*THETA*5X*PHI*7X,
     X *A*9X*B*9X*C*9X*PSI*/)
      END
```

```
      SUBROUTINE CLOUD1                                                 CLOUD1     2
C                                                                       CLOUD1     3
C  GET SOURCE POSITIONS AND DETECTOR POSITION IN CLOUD COORDINATES      CLOUD1     4
C                                                                       CLOUD1     5
CLJ                                                                     CLOUD1     6
CLJ   INPUT PARAMETERS                                                  CLOUD1     7
CLJ      CLOUD COMMON                                                   CLOUD1     8
CLJ          NCLOUD = NUMBER OF DETERMINISTIC CLOUDS (READ IN SUBROUTINE CLOUD1     9
CLJ                   CLOUD0)                                           CLOUD1    10
CLJ      DETECT COMMON                                                  CLOUD1    11
CLJ              HD = ALTITUDE OF DETECTOR,  KM                         CLOUD1    12
CLJ          THETAD = COLATITUDE OF DETECTOR,  DEGREES                  CLOUD1    13
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               CLOUD1    14
CLJ      PARAMS COMMON                                                  CLOUD1    15
CLJ              RE = EARTH'S RADIUS,  KM                               CLOUD1    16
CLJ      SORCE COMMON                                                   CLOUD1    17
CLJ          NSORCE = NUMBER OF SOURCES (CURRENTLY RESTRICTED TO ONE)   CLOUD1    18
CLJ       HSORCE(I) = ALTITUDE OF SOURCE-I ABOVE SURFACE,  KM           CLOUD1    19
CLJ       THETAS(I) = COLATITUDE OF SOURCE-I,  DEGREES                  CLOUD1    20
CLJ         PHIS(I) = EAST LONGITUDE OF SOURCE-I,  DEGREES              CLOUD1    21
CLJ   OUTPUT PARAMETERS                                                 CLOUD1    22
CLJ      CDCORD COMMON                                                  CLOUD1    23
CLJ        XI(I,K), = COORDINATES OF SOURCE-I IN K-TH CLOUD-CENTERED    CLOUD1    24
CLJ       ETA(I,K),   CARTESIAN SYSTEM,  KM        I=1       K=1,20     CLOUD1    25
CLJ      ZETA(I,K)                                                      CLOUD1    26
CLJ         XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED    CLOUD1    27
CLJ        ETAD(K),   CARTESIAN SYSTEM,  KM        K=1,20               CLOUD1    28
CLJ       ZETAD(K)                                                      CLOUD1    29
CLJ                                                                     CLOUD1    30
      COMMON/CLOUD/ NCLOUD,                                             CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),       CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                              CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD     2
     1              XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)      CDCORD     3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD     5
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)       SORCE      2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                              DET        2
      DO 58 K=1,NCLOUD                                                  CLOUD1    36
      DO 55 I=1,NSORCE                                                  CLOUD1    37
C                                                                       CLOUD1    38
      CALL CLD E TO C(RE+HSORCE(I),THETAS(I),PHIS(I),XI(I,K),           CLOUD1    39
     X ETA(I,K),ZETA(I,K),K )                                           CLOUD1    40
C                                                                       CLOUD1    41
   55 CONTINUE                                                          CLOUD1    42
C                                                                       CLOUD1    43
      CALL CLD E TO C(RE +HD,THETAD,PHID,XID(K),ETAD(K),ZETAD(K),K)     CLOUD1    44
C                                                                       CLOUD1    45
   58 CONTINUE                                                          CLOUD1    46
      RETURN                                                            CLOUD1    47
      END                                                               CLOUD1    48
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      SUBROUTINE CLOUD2(UL,VL,WL)                                       CLOUD2     2
CLJ                                                                     CLOUD2     3
CLJ   SUBROUTINE CLOUD2 IS AN AUXILIARY SUBROUTINE, OUTSIDE THE MAIN    CLOUD2     4
CLJ   FLOW OF INFORMATION IN THE DETERMINISTIC CLOUD SUBMODEL.  ITS     CLOUD2     5
CLJ   OUTPUT IS NOT USED BY ANY OF THE OTHER ROUTINES IN THE NATURAL    CLOUD2     6
CLJ   CLOUD MODEL.  HOWEVER, CLOUD2 IS AN IMPORTANT ROUTINE, DESIGNED   CLOUD2     7
CLJ   MAINLY FOR THE USE OF THE SIGHT-PATH-INTEGRATION MODELER IN       CLOUD2     8
CLJ   ROSCOE-IR.  GIVEN THE DIRECTION COSINES OF AN ARBITRARY LOS (NOT  CLOUD2     9
CLJ   NECESSARILY ONE OF THE IMPORTANT SET SELECTED BY SUBROUTINE LOS), CLOUD2    10
CLJ   CLOUD2 WILL DETERMINE WHETHER OR NOT THE LOS INTERCEPTS ANY OF THE CLOUD2   11
CLJ   DETERMINISTIC CLOUDS.  FOR EACH INTERCEPT THE ALTITUDE (ALTLK(K)) CLOUD2    12
CLJ   AND GEOGRAPHIC (POLAR) COORDINATES (THETALK(K),PHILK(K)) OF THE   CLOUD2    13
CLJ   INTERCEPT ARE SET IN INTRCPT COMMON.                              CLOUD2    14
CLJ                                                                     CLOUD2    15
CLJ   INPUT PARAMETERS                                                  CLOUD2    16
CLJ      ARGUMENT LIST                                                  CLOUD2    17
CLJ             UL, = DIRECTION COSINES IN EARTH-CENTERED CARTESIAN     CLOUD2    18
CLJ             VL,   SYSTEM OF A USER-SPECIFIED LOS (SET IN DRIVER)    CLOUD2    19
CLJ             WL                                                      CLOUD2    20
CLJ      CDCORD COMMON                                                  CLOUD2    21
CLJ         XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED    CLOUD2    22
CLJ        ETAD(K),   CARTESIAN SYSTEM,  KM        K=1,20               CLOUD2    23
CLJ       ZETAD(K)                                                      CLOUD2    24
CLJ      CLOUD COMMON                                                   CLOUD2    25
CLJ          NCLOUD = NUMBER OF DETERMINISTIC CLOUDS (READ IN SUBROUTINE CLOUD2   26
CLJ                   CLOUDO)                                           CLOUD2    27
CLJ      DETECT COMMON                                                  CLOUD2    28
CLJ              HD = ALTITUDE OF DETECTOR,  KM                         CLOUD2    29
CLJ          THETAD = COLATITUDE OF DETECTOR,  DEGREES                  CLOUD2    30
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               CLOUD2    31
CLJ      PARAMS COMMON                                                  CLOUD2    32
CLJ             DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS         CLOUD2    33
CLJ              RE = EARTH'S RADIUS,  KM                               CLOUD2    34
CLJ   OUTPUT PARAMETERS                                                 CLOUD2    35
CLJ      INTRCPT COMMON                                                 CLOUD2    36
CLJ        ALTLK(K) = ALTITUDE AT WHICH THE USER-SPECIFIED LOS          CLOUD2    37
CLJ                   INTERCEPTS CLOUD-K,  KM                           CLOUD2    38
CLJ      THETALK(K) = GEOGRAPHIC POLAR COORDINATE AT WHICH THE USER-    CLOUD2    39
CLJ                   SPECIFIED LOS INTERCEPTS CLOUD-K,  DEG            CLOUD2    40
CLJ        PHILK(K) = GEOGRAPHIC AZIMUTHAL COORDINATE AT WHICH THE USER- CLOUD2   41
CLJ                   SPECIFIED LOS INTERCEPTS CLOUD-K,  DEG            CLOUD2    42
CLJ                                                                     CLOUD2    43
      COMMON/CLOUD/ NCLOUD,                                             CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),       CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                              CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                              DET        2
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD     2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD     3
     X , ASQ(20),BSQ(20),CSQ(20)                                        CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD     5
      COMMON/INTRCPT/ ALTLK(20),THETALK(20),PHILK(20)                   INTERCPT   2
      CT = COS(DTR * THETAD)                                            CLOUD2    49
      CP = COS(DTR * PHID)                                              CLOUD2    50
      ST = SIN( DTR*THETAD )                                            CLOUD2    51
      SP = SIN( DTR*PHID )                                              CLOUD2    52
C                                                                       CLOUD2    53
```

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C                                                                        CLOUD2    54
C           TRANSFORM LOS TO CLOUD CENTERED SYSTEM                       CLOUD2    55
CLJ           ADD UNIT LOS VECTOR TO DETECTOR POSITION IN EARTH-CENTERED CLOUD2    56
CLJ           CARTESIAN SYSTEM.                                          CLOUD2    57
         RD = (RD + RE)                                                  CLOUD2    58
         X= RD*ST*CP + UL                                                CLOUD2    59
         Y = RD*ST*SP + VL                                               CLOUD2    60
         Z = RD * CT   + WL                                              CLOUD2    61
C                                                                        CLOUD2    62
         CALL CT TO POL(RH,TH,PH,X,Y,Z)                                  CLOUD2    63
CLJ           NOW HAVE GEOGRAPHIC POLAR COORDINATES (RH,TH,PH) OF TIP OF CLOUD2    64
CLJ           UNIT LOS VECTOR STARTING FROM THE DETECTOR.                CLOUD2    65
         DO 100 K = 1,NCLOUD                                             CLOUD2    66
CLJ           OBTAIN CLOUD-K CARTESIAN COORDINATES OF TIP OF UNIT LOS VECTOR CLOUD2    67
CLJ           (XX,YY,ZZ)                                                 CLOUD2    68
         CALL CLD E TO C (RH,TH,PH,XX,YY,ZZ,K)                           CLOUD2    69
CLJ           NOTE...RHO IS A UNIT VECTOR                                CLOUD2    70
         RHO=SQRT((XID(K)-XX)**2 + (ETAD(K)-YY)**2 +(ZETAD(K)-ZZ)**2  )  CLOUD2    71
         WRITE(6,1001)  K,RH,TH,PH,XX,YY,ZZ,RHO                          CLOUD2    72
    1001 FORMAT (*  PRINTED FROM CLOUD2 -FORMAT 1001  * /                 CLOUD2    73
        1 *  K,RH,TH,PH, XX,YY,ZZ,  RHO  * I2,1P7E13.5)                  CLOUD2    74
C           LINE OF SIGHT VECTOR                                         CLOUD2    75
         ULC =        ( XX -    XID(K))/ RHO                             CLOUD2    76
         VLC =        ( YY -   ETAD(K))/ RHO                             CLOUD2    77
         WLC =        ( ZZ -  ZETAD(K))/ RHO                             CLOUD2    78
C           EVALUATE THE POSITION OF INTERCEPT ON                        CLOUD2    79
C             K-TH CLOUD IN CLOUD COORD SYSTEM                           CLOUD2    80
         A = ULC**2 / ASQ(K) + VLC**2 / BSQ(K) + WLC**2 / CSQ(K)         CLOUD2    81
         B = ULC*XID(K)/ASQ(K)+VLC*ETAD(K)/BSQ(K)+WLC*ZETAD(K)/CSQ(K)    CLOUD2    82
         C=XID(K)**2/ASQ(K) + ETAD(K)**2/BSQ(K) + ZETAD(K)**2/CSQ(K) - 1.  CLOUD2    83
         WRITE(6,1003)K,X,Y,Z,ULC,VLC,WLC,A,B,C                          CLOUD2    84
    1003 FORMAT(1H ,*CLD2 K XYZ UVW ABC*I2,1P9E12.5)                     CLOUD2    85
C           NO INTERCEPT                                                 CLOUD2    86
         IF( B**2 - A*C .LT. 0.) GO TO 100                               CLOUD2    87
         S = ( - B - SQRT(B**2 - A*C) )/A                                CLOUD2    88
         XIL    =    XID(K) + ULC*S                                      CLOUD2    89
         ETAL    =   ETAD(K) + VLC*S                                     CLOUD2    90
         ZETAL   = ZETAD(K) + WLC*S                                      CLOUD2    91
C                                                                        CLOUD2    92
         CALL CLD C TO E ( R,THETALK(K),PHILK(K),XIL,ETAL,ZETAL,K )      CLOUD2    93
         ALTLK(K) = R - RE                                               CLOUD2    94
C                                                                        CLOUD2    95
         WRITE(6,1002) UL,VL,WL,K,ALTLK(K),THETALK(K),PHILK(K)           CLOUD2    96
    1002 FORMAT(* PRINTED FROM CLOUD2 */* THE LOS (* 3E12.4 * ) INTERCEPTS  CLOUD2    97
        XCLOUD *I2*  AT*3E11.3  )                                        CLOUD2    98
     100 CONTINUE                                                        CLOUD2    99
         RETURN                                                          CLOUD2   100
         END                                                             CLOUD2   101
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            SUBROUTINE CLOUD3(UL,VL,WL,K,ALAM,TCOEF,EMISS,SINCLD)               CLOUD3      2
      CLJ                                                                       CLOUD3      3
      CLJ   SUBROUTINE CLOUD3, GIVEN THE DIRECTION COSINES OF A LOS FROM THE    CLOUD3      4
      CLJ   DETECTOR (AS SPECIFIED BY THE DRIVER) FIRST DETERMINES WHETHER OR   CLOUD3      5
      CLJ   NOT THE LOS INTERSECTS CLOUD-K.  IF NO INTERCEPT, TCOEF AND EMISS   CLOUD3      6
      CLJ   ARE SET TO ZERO AND A RETURN IS MADE TO THE CALLING ROUTINE (THE    CLOUD3      7
      CLJ   DRIVER).  IF THE LOS INTERSECTS CLOUD-K, THE ROUTINE CONTINUES.     CLOUD3      8
      CLJ                                                                       CLOUD3      9
      CLJ   THE DO-100 LOOPS COMPUTE THE NORMAL PHOTON FLUX (IRRADIANCE)        CLOUD3     10
      CLJ   INCIDENT ON EACH FACET VIEWED BY THE SOURCE.  SUBROUTINE DIFFUS     CLOUD3     11
      CLJ   THEN IS CALLED TO OBTAIN THE PHOTON FLUX (RADIANT EMITTANCE)        CLOUD3     12
      CLJ   EXITING FROM EACH FACET.                                            CLOUD3     13
      CLJ                                                                       CLOUD3     14
      CLJ   THE DO-200 LOOPS ARE OVER ALL FACETS.                               CLOUD3     15
      CLJ     1. ONE DETERMINES IF THE FACET CENTER IS VISIBLE TO THE DETECTOR CLOUD3     16
      CLJ     2. IF THE FACET CENTER IS VISIBLE TO THE DETECTOR,                CLOUD3     17
      CLJ        A. THE CLOUD-CARTESIAN COORDINATES OF THE FACET CENTER ARE     CLOUD3     18
      CLJ           DETERMINED (XC,ETC,ZETC).                                   CLOUD3     19
      CLJ        B. THE DISTANCE (SDIST) FROM THE FACET CENTER NORMAL TO THE    CLOUD3     20
      CLJ           LOS IS DETERMINED.  THE SMALLEST VALUE OF SDIST IS ALWAYS   CLOUD3     21
      CLJ           SAVED.                                                      CLOUD3     22
      CLJ        C. IF(SDIST.GT.0.7*SQRT(FOV)) AND IF THE CODE HAS PREVIOUSLY   CLOUD3     23
      CLJ           FOUND A FACET CENTER WITHIN (0.7*SQRT(FOV)) OF THE LOS,     CLOUD3     24
      CLJ           INDICATED BY KFLAG=1, THE FACET IS IGNORED.  BUT IF THE     CLOUD3     25
      CLJ           CODE HAS NOT PREVIOUSLY FOUND A FACET CENTER WITHIN         CLOUD3     26
      CLJ           (0.7*SQRT(FOV)) OF THE LOS, INDICATED BY KFLAG=0, AND IF    CLOUD3     27
      CLJ           (SDIST.GT.0.7*SQRT(FOV)), THEN A TRANSFER COEFFICIENT AND   CLOUD3     28
      CLJ           EMISSION WILL BE FOUND FOR ANY FACET FOR WHICH SDIST IS     CLOUD3     29
      CLJ           THE SMALLEST OF THOSE YET PROCESSED.                        CLOUD3     30
      CLJ        D. IF(SDIST.LE.0.7*SQRT(FOV)) THE DIRECTION COSINES TO THE     CLOUD3     31
      CLJ           SOURCE FROM THE FACET CENTER ARE DETERMINED.                CLOUD3     32
      CLJ     3. FURTHER TREATMENT OF THE FACET DEPENDS ON WHETHER OR NOT THE   CLOUD3     33
      CLJ        FACET CENTER IS VISIBLE TO THE SOURCE                          CLOUD3     34
      CLJ        A. IF THE FACET IS NOT VISIBLE TO THE SOURCE, ONE DETERMINES   CLOUD3     35
      CLJ           (1) THE COSINE OF THE ZENITH ANGLE (CTHOUT) TO THE DETECT.  CLOUD3     36
      CLJ           (2) THE AREA (AREAN) OF THE FACET NORMAL TO THE LOS         CLOUD3     37
      CLJ           (3) THE EMISSIVITY (EMISS) OF THE FACET, WEIGHTED BY AREAN CLOUD3     38
      CLJ           (4) THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT         CLOUD3     39
      CLJ               (TCOEF) (AS DETERMINED BY DIFFUSION), WEIGHTED BY       CLOUD3     40
      CLJ               AREAN                                                   CLOUD3     41
      CLJ        B. IF THE FACET IS VISIBLE TO THE SOURCE, ONE DETERMINES       CLOUD3     42
      CLJ           (1) THE INCIDENT ZENITH ANGLE AND THE EXIT ZENITH AND       CLOUD3     43
      CLJ               AZIMUTHAL ANGLE (FOR THE SOURCE-FACET-DETECTOR PATH)    CLOUD3     44
      CLJ               AND THE CORRESPONDING BIDIRECTIONAL REFLECTANCE         CLOUD3     45
      CLJ           (2) THE AREA (AREAN) OF THE FACET NORMAL TO THE LOS         CLOUD3     46
      CLJ           (3) THE EMISSIVITY (EMISS) OF THE FACET, WEIGHTED BY AREAN CLOUD3     47
      CLJ           (4) THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT         CLOUD3     48
      CLJ               (TCOEF) (AS DETERMINED BY BIDIRECTIONAL REFLECTANCE),   CLOUD3     49
      CLJ               WEIGHTED BY AREAN                                       CLOUD3     50
      CLJ        C. THE AVERAGE VALUES OF TCOEF AND EMISS ARE FOUND BY          CLOUD3     51
      CLJ           DIVIDING BY THE SUM OF THE WEIGHTED AREAS AREAN, TAREA,     CLOUD3     52
      CLJ           INCLUDED IN THE CALCULATION.                                CLOUD3     53
      CLJ        D. IF THE FOV IS SO SMALL THAT NO FACET CENTER LIES WITHIN     CLOUD3     54
      CLJ           (0.7*SQRT(FOV)) OF THE LOS, THEN THE SUBROUTINE RETURNS     CLOUD3     55
      CLJ           THE VALUE OF TCOEF AND EMISS FOR THAT FACET-CENTER THAT     CLOUD3     56
      CLJ           IS CLOSEST TO THE LOS.                                      CLOUD3     57
      CLJ   INPUT PARAMETERS                                                    CLOUD3     58
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CLJ        ARGUMENT LIST                                                       CLOUD3    59
CLJ               UL, = DIRECTION COSINES IN EARTH-CENTERED CARTESIAN          CLOUD3    60
CLJ               VL,   SYSTEM OF A USER-SPECIFIED LOS (SET IN DRIVER)         CLOUD3    61
CLJ               WL                                                           CLOUD3    62
CLJ                K = CLOUD NUMBER (SET IN DRIVER)                            CLOUD3    63
CLJ             ALAM = WAVELENGTH, MICRONS (SET IN DRIVER)                     CLOUD3    64
CLJ        ATMOUP COMMON                                                       CLOUD3    65
CLJ               TT = TEMPERATURE OF AMBIENT ATMOSPHERE AT THE ALTITUDE       CLOUD3    66
CLJ                    IN THE ARGUMENT LIST OF SUBROUTINE ATMOSU,  DEG K       CLOUD3    67
CLJ        COCORD COMMON                                                       CLOUD3    68
CLJ         XI(I,K), = COORDINATES OF SOURCE-I IN K-TH CLOUD-CENTERED          CLOUD3    69
CLJ        ETA(I,K),   CARTESIAN SYSTEM,  KM        I=1        K=1,20          CLOUD3    70
CLJ        ZETA(I,K)                                                           CLOUD3    71
CLJ           XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED         CLOUD3    72
CLJ          ETAD(K),   CARTESIAN SYSTEM,  KM         K=1,20                   CLOUD3    73
CLJ         ZETAD(K)                                                           CLOUD3    74
CLJ        CLOUD COMMON                                                        CLOUD3    75
CLJ        HCLOUD(K) = ALTITUDE OF CLOUD-K CENTER ABOVE THE SURFACE,  KM       CLOUD3    76
CLJ       CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE       CLOUD3    77
CLJ                    CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR      CLOUD3    78
CLJ                    ELLIPSOIDAL CLOUD-K,  DEGREES     I=1,8      K=1,20     CLOUD3    79
CLJ     CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF        CLOUD3    80
CLJ                    THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE         CLOUD3    81
CLJ                    FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES                CLOUD3    82
CLJ                          J=1,16     K=1,20                                 CLOUD3    83
CLJ      CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF        CLOUD3    84
CLJ                    SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM              CLOUD3    85
CLJ                        I=1,4       J=1,4      K=1,20                       CLOUD3    86
CLJ                    (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.)      CLOUD3    87
CLJ     CAREA(I,J,K) = AREA OF SURFACE FACET I,J IN PRINCIPAL OCTANT OF        CLOUD3    88
CLJ                    ELLIPSOIDAL CLOUD-K,  KM**2  I=1,4  J=1,4  K=1,20       CLOUD3    89
CLJ           ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN              CLOUD3    90
CLJ                    HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2            CLOUD3    91
CLJ           BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN              CLOUD3    92
CLJ                    HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2            CLOUD3    93
CLJ           CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN              CLOUD3    94
CLJ                    VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2          CLOUD3    95
CLJ        DETECT COMMON                                                       CLOUD3    96
CLJ               HD = ALTITUDE OF DETECTOR, KM                                CLOUD3    97
CLJ           THETAD = COLATITUDE OF DETECTOR, DEGREES                         CLOUD3    98
CLJ             PHID = EAST LONGITUDE OF DETECTOR, DEGREES                     CLOUD3    99
CLJ              FOV = FIELD OF VIEW OF DETECTOR AT EARTH'S SURFACE,KM**2      CLOUD3   100
CLJ        PARAMS COMMON                                                       CLOUD3   101
CLJ              DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS               CLOUD3   102
CLJ               RE = EARTH'S RADIUS,  KM                                     CLOUD3   103
CLJ        FLUX COMMON                                                         CLOUD3   104
CLJ        FOUT(I,J) = 4.*PI TIMES THE OUTGOING PHOTON FLUX (RADIANT           CLOUD3   105
CLJ                    EMITTANCE) FROM ELLIPSOIDAL-SURFACE FACET (I,J)         CLOUD3   106
CLJ                    FOR A UNIT STRENGTH, ISOTROPIC POINT SOURCE             CLOUD3   107
CLJ                    (ONE PHOTON PER SEC), (4.*PI*PHOTONS)/(KM**2 SEC)       CLOUD3   108
CLJ        SORCE COMMON                                                        CLOUD3   109
CLJ           NSORCE = NUMBER OF SOURCES (CURRENTLY RESTRICTED TO ONE)         CLOUD3   110
CLJ        RSORCE(1) = RADIUS OF SOURCE-I,  KM                                 CLOUD3   111
CLJ        XX1111 COMMON                                                       CLOUD3   112
CLJ            KCLDK = A TEST FLAG USED TO DETERMINE WHETHER CLOUD3 IS         CLOUD3   113
CLJ                    NOW BEING CALLED WITH THE SAME CLOUD-NUMBER K AS        CLOUD3   114
CLJ                    FOR ITS LAST CALL.                                      CLOUD3   115
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CLJ          CLDLAM = A TEST QUANTITY USED TO DETERMINE WHETHER CLOUD3   CLOUD3   116
CLJ                   IS NOW BEING CALLED WITH THE SAME WAVELENGTH ALAM  CLOUD3   117
CLJ                   AS FOR ITS LAST CALL.                              CLOUD3   118
CLJ       IF BOTH K AND ALAM INPUTTED TO SUBROUTINE CLOUD3 HAVE THE SAME CLOUD3   119
CLJ       VALUES AS IN THE LAST CALL TO SUBROUTINE CLOUD3, THE           CLOUD3   120
CLJ       SUBROUTINE BYPASSES ITS CALL TO SUBROUTINE DIFFUS(K,ALAM).     CLOUD3   121
CLJ       BOTH KCLDK AND CLDLAM ARE INITIALIZED IN THE MAIN PROGRAM      CLOUD3   122
CLJ       TO THE ARBITRARY, OUT-OF-RANGE VALUES OF 99 AND -99.,          CLOUD3   123
CLJ       RESPECTIVELY.                                                  CLOUD3   124
CLJ   OUTPUT PARAMETERS                                                  CLOUD3   125
CLJ      ARGUMENT LIST                                                   CLOUD3   126
CLJ           TCOEF = IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT AT THE CLOUD3   127
CLJ                   INTERSECTION POINT (IF ANY) BETWEEN THE USER-      CLOUD3   128
CLJ                   SUPPLIED LOS AND CLOUD-K.  THE SOURCE WHICH        CLOUD3   129
CLJ                   IRRADIATES CLOUD-K MAY OR MAY NOT SEE THE          CLOUD3   130
CLJ                   INTERSECTION POINT.  (1/SR)                        CLOUD3   131
CLJ           EMISS = THERMAL EMISSION FROM THE CLOUD AT THE ABOVE-      CLOUD3   132
CLJ                   DESCRIBED INTERSECTION POINT.                      CLOUD3   133
CLJ                      (WATTS/(KM**2 SR MICRON))                       CLOUD3   134
CLJ       BOTH TCOEF AND EMISS ARE MEAN QUANTITIES, AVERAGED OVER A      CLOUD3   135
CLJ       PRESCRIBED PROJECTED AREA (TAREA) OF THE CLOUD IF TAREA        CLOUD3   136
CLJ       EXCEEDS FOV OR OVER FOV IF FOV EXCEEDS TAREA.  THE RADIANCES   CLOUD3   137
CLJ       CORRESPONDING TO TCOEF AND EMISS WILL BE MULTIPLIED BY THE     CLOUD3   138
CLJ       DETECTOR'S FIELD-OF-VIEW SOLID ANGLE, FOV/R**2, TO OBTAIN      CLOUD3   139
CLJ       THE IRRADIANCE AT THE DETECTOR.                                CLOUD3   140
CLJ          SINCLD = LOGICAL VARIABLE SET BY TESTING WHETHER OR NOT     CLOUD3   141
CLJ                   THE SOURCE IS ON OR INSIDE THE SURFACE OF THE      CLOUD3   142
CLJ                   K-TH DETERMINISTIC CLOUD.                          CLOUD3   143
CLJ                   - TRUE , SOURCE ON OR INSIDE SURFACE OF CLOUD      CLOUD3   144
CLJ                   - FALSE, SOURCE OUTSIDE SURFACE OF CLOUD           CLOUD3   145
CLJ      FLUX COMMON                                                     CLOUD3   146
CLJ        FIN(I,J) = 4.*PI TIMES THE INCOMING (NORMAL) PHOTON FLUX      CLOUD3   147
CLJ                   (IRRADIANCE) AT ELLIPSOIDAL-SURFACE FACET (I,J) AT CLOUD3   148
CLJ                   DISTANCE R FROM A UNIT STRENGTH, ISOTROPIC POINT   CLOUD3   149
CLJ                   SOURCE (I.E., (R DOT N)/R**3),   I=1,8    J=1,16   CLOUD3   150
CLJ                      4*PI*PHOTONS/(KM**2 SEC) FOR UNIT SOURCE        CLOUD3   151
CLJ                                                                      CLOUD3   152
      COMMON/CLOUD/ NCLOUD,                                              CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),        CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                               CLOUD      4
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                   CDCORD     2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)      CDCORD     3
     X  , ASQ(20),BSQ(20),CSQ(20)                                        CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)          CDCORD     5
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                             PARAMS     2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                               DET        2
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)        SORCE      2
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                            ATMOSX     2
      COMMON/FLUX/  FIN(8,16),FOUT(8,16)                                 FLUX       2
      COMMON/XX1111/  KCLDK, CLDLAM                                      CLOUD3   160
      LOGICAL  SINCLD                                                    CLOUD3   161
CLJ       THE ARITHMETIC FUNCTION PLANK(AA,TT) EVALUATES THE PLANCK      CLOUD3   162
CLJ       SPECTRAL FUNCTION AT WAVELENGTH AA=ALAM(MICRONS) AND           CLOUD3   163
CLJ       TEMPERATURE TT(DEG K),  WATTS/(KM**2 SR MICRON)                CLOUD3   164
      PLANK(AA,TT) = 1.191E14/(AA**5*(EXP(14388./(AA*TT))-1.))           CLOUD3   165
C                                                                        CLOUD3   166
C        UL,VL,WL  ARE THE DIRECTION COSINES OF L-O-S                    CLOUD3   167
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C         IN THE EARTH SYSTEM                                            CLOUD3 168
C                                                                        CLOUD3 169
C         GENERATE THE FIN ARRAY BY CYCLING THROUGH THE SOURCES,         CLOUD3 170
C         ADDING THE CONTRIBUTION OF EACH TO EVERY FIN(I,J)              CLOUD3 171
C              ENTER WITH A SIGHT-PATH IN EARTH COORDINATES,             CLOUD3 172
C         CLOUD NUMBER,  WAVELENGTH, AND A SET OF NSORCE SOURCES.        CLOUD3 173
CLJ            THE SOURCES ARE IN COMMON/SORCE/ WHICH HAS TO BE FILLED   CLOUD3 174
CLJ       BY THE USER.  DUPLICATE THE INSTRUCTIONS FROM CLOUD2 TO        CLOUD3 175
CLJ       TRANSFORM LOS TO CLOUD-CENTERED CARTESIAN SYSTEM.              CLOUD3 176
      RD = (HD + RE)                                                     CLOUD3 177
      ST = SIN( DTR*THETAD )                                             CLOUD3 178
      SP = SIN( DTR*PHID )                                               CLOUD3 179
      CT = COS( DTR*THETAD )                                             CLOUD3 180
      CP = COS( DTR*PHID )                                               CLOUD3 181
      X = RD * ST* CP + UL                                               CLOUD3 182
      Y = RD * ST * SP + VL                                              CLOUD3 183
      Z = RD * CT      + WL                                              CLOUD3 184
      WRITE(6,1001)K,X,Y,Z,SQRT(X**2+Y**2+Z**2),UL,VL,WL                 CLOUD3 185
 1001 FORMAT(* CLOUD3 FORMAT 1001 ---K,XYZ,R,UVW* I3,1P7E11.3 )          CLOUD3 186
C                                                                        CLOUD3 187
      CALL CT TO POL(RHO,TH,PHI,X,Y,Z)                                   CLOUD3 188
      CALL CLD E TO C (RHO,TH,PHI,XX,YY,ZZ,K)                            CLOUD3 189
C        LOS VECTOR IN THE K-TH CLOUD COORD SYSTEM                       CLOUD3 190
CLJ       NOTE...RHO IS OF UNIT LENGTH.                                  CLOUD3 191
      RHO=SQRT( (XX-XID(K))**2 + (YY-ETAD(K))**2 + (ZZ-ZETAD(K))**2  )   CLOUD3 192
      ULC =     ( XX -     XID(K))/ RHO                                  CLOUD3 193
      VLC =     ( YY -    ETAD(K))/ RHO                                  CLOUD3 194
      WLC =     ( ZZ -   ZETAD(K))/ RHO                                  CLOUD3 195
C                                                                        CLOUD3 196
C         EVALUATE THE POSITION OF INTERCEPT ON                          CLOUD3 197
C         K-TH CLOUD IN CLOUD COORD SYSTEM                               CLOUD3 198
      A = ULC**2 / ASQ(K) + VLC**2 / BSQ(K) + WLC**2 / CSQ(K)            CLOUD3 199
      B = ULC*XID(K)/ASQ(K)+VLC*ETAD(K)/BSQ(K)+WLC*ZETAD(K)/CSQ(K)       CLOUD3 200
      C = XID(K)**2 / ASQ(K) + ETAD(K)**2/BSQ(K) + ZETAD(K)**2/CSQ(K)-1. CLOUD3 201
      IF ( (B**2 - A*C ) .GT. 0.) GO TO 15                               CLOUD3 202
      TCOEF = 0.                                                         CLOUD3 203
      EMISS = 0.0                                                        CLOUD3 204
      WRITE(6,10) UL,VL,WL,K                                             CLOUD3 205
   10 FORMAT(*   CAUTION--- LOS (*3E12.5* ) DIDNT INTERSECT CLOUD *I4,*  CLOUD3 206
     1 PRINTED FROM FORMAT 10 CLOUD3  *)                                 CLOUD3 207
      RETURN                                                             CLOUD3 208
   15 CONTINUE                                                           CLOUD3 209
      S = ( - B - SQRT(B**2 - A*C) )/A                                   CLOUD3 210
CLJ       XIL, ETAL, ZETAL ARE THE COORDINATES OF THE INTERCEPT POINT    CLOUD3 211
CLJ       IN THE CLOUD-CENTERED CARTESIAN SYSTEM.                        CLOUD3 212
      XIL    =   XID(K) + ULC*S                                          CLOUD3 213
      ETAL   =  ETAD(K) + VLC*S                                          CLOUD3 214
      ZETAL  = ZETAD(K) + WLC*S                                          CLOUD3 215
      WRITE(6,1003)K,XIL,ETAL,ZETAL,SQRT(XIL**2+ETAL**2+ZETAL**2),S,ULC, CLOUD3 216
     X VLC,WLC                                                           CLOUD3 217
 1003 FORMAT(* 2 K XIL ETAL ZETAL R S ULC V W*I3,1P8E10.2)               CLOUD3 218
      CIPALT = HCLOUD(K) + ZETAL                                         CLOUD3 219
      CALL ATMOSU(2,CIPALT)                                              CLOUD3 220
      TK = TT                                                            CLOUD3 221
CLJ       WE HAVE JUST COMPUTED THE TEMPERATURE, TK, AT THE INTERCEPT    CLOUD3 222
CLJ       POINT THAT WILL BE USED LATER IN THE PLANCK FUNCTION WHEN      CLOUD3 223
CLJ       COMPUTING THE EMISSION.  WE IGNORE ANY DEPARTURE OF THE        CLOUD3 224
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CLJ       CLOUD TEMPERATURE FROM THIS SINGLE VALUE.                      CLOUD3   225
C                                                                        CLOUD3   226
CLJ     LOOP OVER THE CLOUD-SURFACE FACETS (CTHBAR AND CPHIBAR)          CLOUD3   227
CLJ       I - INDEX ON CTHBAR                                            CLOUD3   228
CLJ       J - INDEX ON CPHIBAR                                           CLOUD3   229
CLJ       IP - FIRST-OCTANT INDEX CORRESPONDING TO I                     CLOUD3   230
CLJ       JP - FIRST-OCTANT INDEX CORRESPONDING TO J                     CLOUD3   231
C                                                                        CLOUD3   232
      NS = 1                                                             CLOUD3   233
CLJ       BEFORE COMPUTING SOURCE-IRRADIATION OF CLOUD-K, CHECK WHETHER  CLOUD3   234
CLJ       SOURCE IS INSIDE CLOUD-K.  IF IT IS, PRINT A WARNING MESSAGE   CLOUD3   235
CLJ       TO THAT EFFECT AND RETURN TO DRIVER PROGRAM WITHOUT ATTEMPTING CLOUD3   236
CLJ       FURTHER CALCULATIONS.  (WE MAY BE ABLE TO DEVELOP AN APPROX.   CLOUD3   237
CLJ       TREATMENT LATER.)                                              CLOUD3   238
      SINCLD = ( (XI(NS,K)**2 / ASQ(K) + ETA(NS,K)**2 / BSQ(K)          CLOUD3   239
     $         + ZETA(NS,K)**2 / CSQ(K)) .LE. 1.0 )                      CLOUD3   240
      IF( .NOT.SINCLD ) GO TO 80                                         CLOUD3   241
      WRITE(6,1005)  NS, K                                               CLOUD3   242
 1005 FORMAT (*0  SOURCE *,I4,* IS INSIDE (OR POSSIBLY ON THE SURFACE)*, CLOUD3   243
     1 * OF CLOUD-K =*,I4 / *   THEREFORE NO ATTEMPT HAS BEEN MADE TO*,  CLOUD3   244
     2 * COMPUTE THE SOURCE-IRRADIATION OF CLOUD-K. *)                   CLOUD3   245
      RETURN                                                             CLOUD3   246
   80 CONTINUE                                                           CLOUD3   247
C                                                                        CLOUD3   248
CLJ       WE TAKE (APPROXIMATE) ACCOUNT OF THE FINITE SIZE OF AN         CLOUD3   249
CLJ       ARTIFICIAL SOURCE WHEN ITS DISTANCE FROM THE SURFACE OF A      CLOUD3   250
CLJ       CLOUD IS LESS THAN (APPROXIMATELY) THE RADIUS, RSORCE(1),      CLOUD3   251
CLJ       ASSIGNED TO THE SOURCE.  WE DO THIS BY RESETTING THE SOURCE    CLOUD3   252
CLJ       POSITION, THEREBY PREVENTING THE OCCURRENCE OF AN ARBITRARILY  CLOUD3   253
CLJ       SMALL DISTANCE FROM THE (POINT) SOURCE TO THE CLOUD SURFACE.   CLOUD3   254
CLJ       THE TECHNIQUE IS SIMILAR TO THAT EMPLOYED IN THE STATISTICAL   CLOUD3   255
CLJ       CLOUD SUBMODEL TO PREVENT CALCULATING ARBITRARILY LARGE        CLOUD3   256
CLJ       TRANSFER COEFFICIENTS FOR REFLECTION.                          CLOUD3   257
CLJ       THE DISTANCE RP FROM THE CENTER OF CLOUD-K TO SOURCE NS=1 IS   CLOUD3   258
CLJ                                                                      CLOUD3   259
      RP = SQRT( XI(1,K)**2 + ETA(1,K)**2 + ZETA(1,K)**2 )               CLOUD3   260
CLJ                                                                      CLOUD3   261
CLJ       THE DIRECTION COSINES, IN THE CLOUD-K COORDINATE SYSTEM, OF    CLOUD3   262
CLJ       THE SOURCE POSITION ARE...                                     CLOUD3   263
      RPX =  XI(1,K)/RP                                                  CLOUD3   264
      RPY =  ETA(1,K)/RP                                                 CLOUD3   265
      RPZ = ZETA(1,K)/RP                                                 CLOUD3   266
CLJ       THE CLOUD-K COORDINATES X,Y,Z AT WHICH THE RAY TO THE SOURCE   CLOUD3   267
CLJ       INTERSECTS THE CLOUD SURFACE ARE GIVEN BY                      CLOUD3   268
CLJ           X = RS*RPX,    Y = RS*RPY,    Z = RS*RPZ                   CLOUD3   269
CLJ       WHERE RS IS THE RADIAL DISTANCE TO THE POINT X,Y,Z, OBTAINED   CLOUD3   270
CLJ       BY SUBSTITUTING THE ABOVE EXPRESSIONS FOR X,Y,Z INTO THE       CLOUD3   271
CLJ       EQUATION FOR AN ELLIPSOID AND SOLVING FOR RS...                CLOUD3   272
CLJ                                                                      CLOUD3   273
      RS = 1.0/SQRT( RPX*RPX/ASQ(K) + RPY*RPY/BSQ(K) + RPZ*RPZ/CSQ(K) )  CLOUD3   274
CLJ                                                                      CLOUD3   275
CLJ       THE DISTANCE RPMRS OF THE SOURCE FROM THE CLOUD SURFACE,       CLOUD3   276
CLJ       MEASURED ALONG THE RAY RP, IS...                               CLOUD3   277
CLJ                                                                      CLOUD3   278
      RPMRS = RP - RS                                                    CLOUD3   279
      X = RS*RPX                                                         CLOUD3   280
      Y = RS*RPY                                                         CLOUD3   281
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      Z = RS*RPZ                                                        CLOUD3
CLJ                                                                     CLOUD3
CLJ         AT THE INTERSECTION POINT X,Y,Z THE UNIT OUTWARD NORMAL HAS CLOUD3
CLJ         COMPONENTS VX,VY,VZ, OBTAINED FROM SUBROUTINE VXNORM...     CLOUD3
CLJ                                                                     CLOUD3
      CALL VSNORM(X,Y,Z,VX,VY,VZ,K)                                     CLOUD3
CLJ                                                                     CLOUD3
CLJ         SAVE ORIGINAL SOURCE POSITION.                              CLOUD3
      XISV   =    XI(1,K)                                               CLOUD3
      ETASV  =   ETA(1,K)                                               CLOUD3
      ZETASV = ZETA(1,K)                                                CLOUD3
CLJ         THE COMPONENT OF RPMRS IN THE DIRECTION OF THE UNIT NORMAL AT CLOUD3
CLJ         THE POINT X,Y,Z IS (V DOT RPMRS = V DOT SP), I.E.,          CLOUD3
      VDOTSP = ( VX*RPX + VY*RPY + VZ*RPZ ) * RPMRS                     CLOUD3
      IF( VDOTSP.GE.RSORCE(1) )  GO TO 40                               CLOUD3
CLJ         OTHERWISE, WE MOVE THE SOURCE A DISTANCE DELP IN THE DIRECTION CLOUD3
CLJ         OF THE UNIT NORMAL AT X,Y,Z, HAVING SAVED THE ORIGINAL SOURCE CLOUD3
CLJ         POSITION.  (WE USE THIS PARTICULAR UNIT NORMAL BECAUSE IT IS CLOUD3
CLJ         READILY FOUND, WHEREAS THE PERPENDICULAR FROM THE SOURCE TO CLOUD3
CLJ         THE CLOUD SURFACE IS NOT READILY FOUND.)                    CLOUD3
      DELP = 0.5*(RSORCE(1)-VDOTSP)                                     CLOUD3
      XI(1,K)   =   XI(1,K) + DELP*VX                                   CLOUD3
      ETA(1,K)  =  ETA(1,K) + DELP*VY                                   CLOUD3
      ZETA(1,K) = ZETA(1,K) + DELP*VZ                                   CLOUD3
      WRITE(6,1006)  NS,K,XISV,ETASV,ZETASV,XI(1,K),ETA(1,K),ZETA(1,K)  CLOUD3
 1006 FORMAT (*0    MESSAGE FROM SUBROUTINE CLOUD3  */                  CLOUD3
     1 *0    THE COORDINATES OF SOURCE NS=*,I4,* , RELATIVE TO CLOUD K=*, CLOUD3
     2 I4,* , HAVE BEEN CHANGED...*/                                    CLOUD3
     3 *     FROM XI,ETA,ZETA =*,3E14.5/*        TO XI,ETA,ZETA =*,3E14.5) CLOUD3
   40 CONTINUE                                                          CLOUD3
      IF( (K.EQ.KCLDK) .AND. (ALAM.EQ.CLDLAM) )  GO TO 110              CLOUD3
CLJ         START LOOP TO COMPUTE SOURCE-IRRADIATION OF CLOUD-K         CLOUD3
CLJ         OBTAIN FIN(I,J)                                             CLOUD3
      DO 100 I = 1,8                                                    CLOUD3
      IP = IPRIME(I)                                                    CLOUD3
      DO 100 J = 1,16                                                   CLOUD3
      JP = IPRIME(J)                                                    CLOUD3
      FIN(I,J) = 0.                                                     CLOUD3
C           CHECK TO SEE IF AREA(I,J) IS VISIBLE TO SOURCE              CLOUD3
C           IF NOT, GO TO NEXT AREA                                     CLOUD3
      IF(PS(XI(NS,K),ETA(NS,K),ZETA(NS,K),CTHBAR(I,K),CPHIBAR(J,K),K)   CLOUD3
     1  .LE. 0) GO TO 100                                               CLOUD3
C                                                                       CLOUD3
CLJ         GET CLOUD-FACET CENTER IN CLOUD-CENTERED CARTESIAN          CLOUD3
CLJ         COORDINATES (XC,ETC,ZETC)                                   CLOUD3
      CALLPOL TO CT(CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),XC,ETC,ZETC) CLOUD3
C                                                                       CLOUD3
CLJ         GET UNIT VECTOR NORMAL TO ELLIPSOIDAL SURFACE AT (XC,ETC,ZETC) CLOUD3
C         CALL IT AN1,AN2,AN3                                           CLOUD3
      CALL VSNORM(XC,ETC,ZETC,AN1,AN2,AN3,K)                            CLOUD3
CLJ         RSQ=SQUARE OF DISTANCE FROM SOURCE TO VISIBLE FACET-CENTER  CLOUD3
      RSQ=(XC-XI(NS,K))**2 + (ETC-ETA(NS,K))**2 + (ZETC-ZETA(NS,K))**2  CLOUD3
      FIN(I,J) = FIN(I,J) -                                             CLOUD3
     1 (AN1*(XC-XI(NS,K))+ AN2*(ETC-ETA(NS,K))+AN3*(ZETC-ZETA(NS,K)))   CLOUD3
     1   / SQRT(RSQ)**3                                                 CLOUD3
  100 CONTINUE                                                          CLOUD3
CLJ                                                                     CLOUD3
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C        CALCULATE FOUT                                                   CLOUD3   339
      CALL DIFFUS(K,ALAM)                                                 CLOUD3   340
C                                                                         CLOUD3   341
  110 KCLDK = K                                                           CLOUD3   342
      CLDLAM = ALAM                                                       CLOUD3   343
C        LOOP OVER ALL AREAS VISIBLE TO AND IN FOV OF DETECTOR            CLOUD3   344
C        SUM THE TOTAL AREA OF THE CLOUD FACETS NORMAL TO LOS             CLOUD3   345
C                                                                         CLOUD3   346
      EMISS = 0.                                                          CLOUD3   347
      TCOEF = 0.                                                          CLOUD3   348
      TAREA = 0.                                                          CLOUD3   349
CLJ       TO FORCE THE SUBROUTINE TO COMPUTE AND RETURN NOT ZEROS BUT     CLOUD3   350
CLJ       THE BEST POSSIBLE ANSWERS FOR TCOEF AND EMISS WHEN NO FACET     CLOUD3   351
CLJ       CENTER IS WITHIN (0.7*SQRT(FOV)) OF THE LOS, WE INTRODUCE TWO   CLOUD3   352
CLJ       VARIABLES, SSAVE AND KFLAG, TO FACILITATE TREATING THIS SMALL-  CLOUD3   353
CLJ       FOV CONDITION.  SSAVE ULTIMATELY BECOMES THE SMALLEST VALUE OF  CLOUD3   354
CLJ       SDIST FOR THE SMALL-FOV CONDITION BUT IT IS INITIALIZED TO AN   CLOUD3   355
CLJ       ARBITRARILY LARGE VALUE.  KFLAG IS INITIALIZED TO 0 BUT IS      CLOUD3   356
CLJ       RESET TO 1 IF AND WHEN THE CODE FINDS A FACET CENTER WITHIN     CLOUD3   357
CLJ       (0.7*SQRT(FOV)) OF THE LOS.                                     CLOUD3   358
      SSAVE = 1.0E+10                                                     CLOUD3   359
      KFLAG = 0                                                           CLOUD3   360
      DO 200 I = 1,8                                                      CLOUD3   361
      IP = IPRIME(I)                                                      CLOUD3   362
      DO 200 J = 1,16                                                     CLOUD3   363
      JP = IPRIME(J)                                                      CLOUD3   364
CLJ       IF FACET CENTER IS NOT VISIBLE TO DETECTOR, GO TO NEXT FACET    CLOUD3   365
      IF(PS(XID(K),ETAD(K),ZETAD(K),CTHBAR(I,K),CPHIBAR(J,K),K)           CLOUD3   366
     1  .LT. 0.) GO TO 200                                                CLOUD3   367
      CALLPOL TC CT(CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),XC,ETC,ZETC)  CLOUD3   368
      CALL VSNORM(XC,ETC,ZETC,AN1,AN2,AN3,K)                              CLOUD3   369
C                                                                         CLOUD3   370
CLJ       THE CURRENT(I,J)-FACET CENTER IS VISIBLE TO A WIDE-ANGLE        CLOUD3   371
CLJ       DETECTOR, BUT IS IT WITHIN THE FOV OF THE DETECTOR SPECIFIED.   CLOUD3   372
CLJ       LET SDIST BE THE DISTANCE, (APPROXIMATELY) NORMAL TO THE LOS,   CLOUD3   373
CLJ       TO THE FACET CENTER.                                            CLOUD3   374
CLJ       GET ARG, THE COSINE OF THE ANGLE BETWEEN THE LOS AND THE        CLOUD3   375
CLJ       DIRECTION TO THE FACET CENTER FROM THE DETECTOR.                CLOUD3   376
CLJ       LET SDIST TEMPORARILY BE THE INVERSE DISTANCE FROM THE          CLOUD3   377
CLJ       DETECTOR TO THE FACET CENTER.                                   CLOUD3   378
      SDIST = 1.                                                          CLOUD3   379
     1   / SQRT( (XC-XID(K))**2+(ETC-ETAD(K))**2+(ZETC-ZETAD(K))**2)      CLOUD3   380
      ARG =(ULC*(XC-XID(K)) + VLC*(ETC-ETAD(K))+WLC*(ZETC-ZETAD(K)) )     CLOUD3   381
     1  * SDIST                                                           CLOUD3   382
      IF(ABS(ARG) .GT. 1.) ARG = 1.                                       CLOUD3   383
      SDIST = ACOS(ARG) / SDIST                                           CLOUD3   384
      IF( SDIST.GT.SSAVE )  GO TO 150                                     CLOUD3   385
      SSAVE = SDIST                                                       CLOUD3   386
  150 IF( (KFLAG.EQ.1) .AND. (SDIST.GT.0.7*SQRT(FOV)) )  GO TO 200        CLOUD3   387
CLJ       RR=DISTANCE FROM THE SOURCE TO THE FACET CENTER                 CLOUD3   388
      RR = SQRT( (XC - XI(NS,K))**2 + (ETC-ETA (NS,K))**2 +               CLOUD3   389
     1  (ZETC - ZETA(NS,K) )**2  )                                        CLOUD3   390
CLJ       ULS,VLS,WLS ARE THE DIRECTION COSINES OF A UNIT VECTOR TOWARD   CLOUD3   391
CLJ       THE SOURCE FROM A FACET CENTER THAT IS EITHER WITHIN THE FOV    CLOUD3   392
CLJ       OF THE DETECTOR OR IS A CANDIDATE FOR BEING THE CLOSEST TO      CLOUD3   393
CLJ       THE FOV.                                                        CLOUD3   394
      ULS = (XI(NS,K)-XC)/RR                                              CLOUD3   395
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      VLS = (ETA(NS,K)-ETC)/RR                                           CLOUD3
      WLS = (ZETA(NS,K)-ZETC)/RR                                         CLOUD3
CLJ       IF THE DETECTOR-VIEWED FACET-CENTER IS VISIBLE TO THE SOURCE,  CLOUD3
CLJ       SKIP TO STATEMENT-201 TO COMPUTE THE TRANSFER COEFFICIENT      CLOUD3
CLJ       FOR REFLECTANCE.                                               CLOUD3
      IF(PS(XI(NS,K),ETA(NS,K),ZETA(NS,K),CTHBAR(I,K),CPHIBAR(J,K),K)    CLOUD3
     1 .GT. 0) GO TO 201                                                 CLOUD3
CLJ       THE DETECTOR-VIEWED FACET-CENTER IS NOT VISIBLE TO THE SOURCE  CLOUD3
CLJ       SO COMPUTE THE TRANSFER COEFFICIENT FOR TRANSMISSION.          CLOUD3
      CTHOUT = -( AN1*ULC+AN2*VLC+AN3*WLC)                               CLOUD3
      AREAN = CTHOUT * CAREA(IP,JP,K)                                    CLOUD3
      IF( (KFLAG.EQ.1) .OR. (SDIST.LE.0.7*SQRT(FOV)) )  GO TO 160        CLOUD3
      IF( SDIST.NE.SSAVE )  GO TO 200                                    CLOUD3
      ESAVE = (1.-RHOEPS(ALAM,CTHOUT)) * PLANK(ALAM,TK) * AREAN          CLOUD3
      TSAVE = 0.25*AREAN*FOUT(I,J)/(PI*PI)                               CLOUD3
      ASAVE = AREAN                                                      CLOUD3
      GO TO 200                                                          CLOUD3
  160 CONTINUE                                                           CLOUD3
      EMISS = EMISS + (1. - RHOEPS(ALAM,CTHOUT))*PLANK(ALAM,TK)*AREAN    CLOUD3
CLJ       THE FOLLOWING EXPRESSION FOR TCOEF, WHILE CORRECT AS USED,     CLOUD3
CLJ       LACKS BEING A TRANSFER COEFFICIENT (FOR TRANSMISSION) BECAUSE  CLOUD3
CLJ       (1) IT LACKS THE FACTORS 4.*PI*DISTANCE**2 SUPPLIED AT THE END CLOUD3
CLJ       OF THE ROUTINE AND (2) IT INCLUDES A WEIGHTING FACTOR, AREAN,  CLOUD3
CLJ       USED IN DETERMINING AN AVERAGE VALUE.  (STRICTLY, A FACTOR     CLOUD3
CLJ       DISTANCE**2 SHOULD HAVE BEEN INCLUDED IN THE QUANTITY BEING    CLOUD3
CLJ       AVERAGED.)  THE FACTOR 0.25/PI COMPENSATES FOR THE RADIANT     CLOUD3
CLJ       EXITANCE, FOUT, BEING LARGE BY A FACTOR OF 4.*PI.  THE FACTOR  CLOUD3
CLJ       1./PI CONVERTS THE RADIANT EXITANCE TO RADIANCE.               CLOUD3
      TCOEF = FOUT(I,J) / PI**2*0.25 * AREAN + TCOEF                     CLOUD3
      TAREA = TAREA + AREAN                                              CLOUD3
CLJ       WE HAVE FOUND A FACET CENTER WITHIN (0.7*SQRT(FOV)) OF THE     CLOUD3
CLJ       LOS SO SET KFLAG EQUAL TO 1.                                   CLOUD3
      KFLAG = 1                                                          CLOUD3
      GO TO 200                                                          CLOUD3
  201 CONTINUE                                                           CLOUD3
CLJ       THE DETECTOR-VIEWED FACET-CENTER IS VISIBLE TO THE SOURCE.     CLOUD3
      CTHIN = ULS * AN1 + VLS * AN2 + WLS * AN3                          CLOUD3
      CTHOUT = -( AN1*ULC+AN2*VLC+AN3*WLC)                               CLOUD3
      AREAN = CTHOUT * CAREA(IP,JP,K)                                    CLOUD3
      THE = ACOS( CTHOUT )                                               CLOUD3
      THI = ACOS( CTHIN )                                                CLOUD3
      CPHOUT = 1.0                                                       CLOUD3
      IF( (THE.EQ.0.0) .OR. (THI.EQ.0.0) )  GO TO 165                    CLOUD3
      CPHOUT = (CTHOUT*CTHIN + (ULS*ULC + VLS*VLC + WLS*WLC)) /          CLOUD3
     $         (SIN(THE) * SIN(THI))                                     CLOUD3
  165 CONTINUE                                                           CLOUD3
      IF( (KFLAG.EQ.1) .OR. (SDIST.LE.0.7*SQRT(FOV)) )  GO TO 170        CLOUD3
      IF( SDIST.NE.SSAVE )  GO TO 200                                    CLOUD3
      ESAVE = (1.-RHOEPS(ALAM,CTHOUT)) * PLANK(ALAM,TK) * AREAN          CLOUD3
      TSAVE = CLDBDR(CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD(K))                 CLOUD3
     $  * AREAN*FIN(I,J)/(4.*PI)                                         CLOUD3
      ASAVE = AREAN                                                      CLOUD3
      GO TO 200                                                          CLOUD3
  170 CONTINUE                                                           CLOUD3
CLJ       THE FOLLOWING EXPRESSION FOR TCOEF, WHILE (ESSENTIALLY)        CLOUD3
CLJ       CORRECT AS USED, LACKS BEING A TRANSFER COEFFICIENT (FOR       CLOUD3
CLJ       REFLECTANCE) BECAUSE (1) IT (EFFECTIVELY) INCLUDES IN ITS      CLOUD3
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CLJ       DENOMINATOR THE FACTORS 4.*PI*DISTANCE**2 TO COMPENSATE FOR      CLOUD3    453
CLJ       THE SIMILAR FACTORS SUPPLIED AT THE END OF THE ROUTINE AND (2)  CLOUD3    454
CLJ       IT INCLUDES A WEIGHTING FACTOR, AREAN, USED IN DETERMINING AN   CLOUD3    455
CLJ       AVERAGE VALUE.  THE USE OF FIN(I,J) IS A WAY OF INTRODUCING     CLOUD3    456
CLJ       THE REQUIRED CTHIN FACTOR AND THE COMPENSATING 1./DISTANCE**2   CLOUD3    457
CLJ       FACTOR.  (STRICTLY, THE VARIOUS FACTORS OF DISTANCE**2 USED     CLOUD3    458
CLJ       HERE DO NOT EXACTLY COMPENSATE FOR THE SINGLE DISTANCE**2       CLOUD3    459
CLJ       FACTOR USED AT THE END OF THE ROUTINE.)                         CLOUD3    460
      TCOEF = AREAN*FIN(I,J)*CLDBDR(CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD(K))   CLOUD3    461
     $  / (4.*PI) + TCOEF                                                 CLOUD3    462
      TAREA = TAREA + AREAN                                               CLOUD3    463
      EMISS = EMISS + (1. - RHOEPS(ALAM,CTHOUT))*PLANK(ALAM,TK)*AREAN     CLOUD3    464
      KFLAG = 1                                                           CLOUD3    465
  200 CONTINUE                                                            CLOUD3    466
C         XIL,ETAL,ZETAL IS THE POSITION IN THE K'TH CLOUD COORDINATE     CLOUD3    467
C         SYSTEM OF INTERSECTION ..  GET DISTANCE FROM SOURCE TO THIS PT  CLOUD3    468
CLJ       RDIST2=SQUARE OF DISTANCE FROM SOURCE TO CLOUD-INTERCEPT POINT  CLOUD3    469
      RDIST2 = (XIL - XI(NS,K))**2 + (ETAL - ETA(NS,K))**2                CLOUD3    470
     X   + (ZETAL - ZETA(NS,K))**2                                        CLOUD3    471
      IF( TCOEF.GT.0.0 )  GO TO 220                                       CLOUD3    472
      EMISS = ESAVE                                                       CLOUD3    473
      TCOEF = TSAVE                                                       CLOUD3    474
      TAREA = ASAVE                                                       CLOUD3    475
CLJ       IN THE FOLLOWING TWO EXPRESSIONS THE DIVISION BY FOV IF FOV     CLOUD3    476
CLJ       EXCEEDS TAREA (WHEN THE CLOUD EFFECTIVELY BECOMES A POINT       CLOUD3    477
CLJ       SOURCE) IS PROPER IF THE USER MULTIPLIES THE RADIANCES          CLOUD3    478
CLJ       CORRESPONDING TO TCOEF AND EMISS BY THE SOLID ANGLE OF THE      CLOUD3    479
CLJ       DETECTOR, FOV/R**2, TO OBTAIN THE IRRADIANCE AT THE DETECTOR,   CLOUD3    480
CLJ       AT DISTANCE R FROM THE CLOUD.                                   CLOUD3    481
  220 TAFOV = AMAX1( TAREA,FOV )                                          CLOUD3    482
      TCOEF = TCOEF / TAFOV * (4.*PI*RDIST2)                              CLOUD3    483
      EMISS = EMISS / TAFOV                                               CLOUD3    484
CLJ       RESTORE SOURCE POSITION...                                      CLOUD3    485
      XI(1,K)    =    XISV                                                CLOUD3    486
      ETA(1,K)   =   ETASV                                                CLOUD3    487
      ZETA(1,K) = ZETASV                                                  CLOUD3    488
      RETURN                                                              CLOUD3    489
      END                                                                 CLOUD3    490
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      SUBROUTINE CLOUD9(RTP1,RTP2,RTP3,EC1,EC2,EC3,K)                   CLOUD9    2
CLJ                                                                     CLOUD9    3
CLJ   SUBROUTINE CLOUD9 HAS TWO ENTRY POINTS.                           CLOUD9    4
CLJ   ENTRY-(CLD E TO C) CONVERTS FROM GEOGRAPHIC POLAR COORDINATES TO  CLOUD9    5
CLJ   CLOUD-CENTERED CARTESIAN COORDINATES.                             CLOUD9    6
CLJ   ENTRY-(CLD C TO E) CONVERTS FROM CLOUD-CENTERED CARTESIAN         CLOUD9    7
CLJ   COORDINATES TO GEOGRAPHIC POLAR COORDINATES.                      CLOUD9    8
CLJ                                                                     CLOUD9    9
CLJ   INPUT PARAMETERS                                                  CLOUD9   10
CLJ      ARGUMENT LIST (FOR ENTRY CLD E TO C)                           CLOUD9   11
CLJ           RTP1, = GEOGRAPHIC POLAR COORDINATES (RTP1=RADIUS, KM.    CLOUD9   12
CLJ           RTP2,      RTP2=POLAR ANGLE (COLATITUDE), DEG.            CLOUD9   13
CLJ           RTP3       RTP3=AZIMUTHAL ANGLE (EAST LONGITUDE), DEG.)   CLOUD9   14
CLJ               K = CLOUD NUMBER                                      CLOUD9   15
CLJ      ARGUMENT LIST (FOR ENTRY CLD C TO E)                           CLOUD9   16
CLJ            EC1, = CLOUD-K CENTERED CARTESIAN COORDINATES, KM        CLOUD9   17
CLJ            EC2, AND EC3                                             CLOUD9   18
CLJ               K = CLOUD NUMBER                                      CLOUD9   19
CLJ      CLOUD COMMON                                                   CLOUD9   20
CLJ       THETCD(K) = COLATITUDE OF CLOUD-K, DEG                        CLOUD9   21
CLJ        PHICD(K) = EAST LONGITUDE OF CLOUD-K, DEG                    CLOUD9   22
CLJ       CLDPSI(I) = AZIMUTHAL ANGLE, MEASURED COUNTERCLOCKWISE        CLOUD9   23
CLJ                   LOOKING DOWN, ORIENTING CLOUD ABOUT (VERTICAL)    CLOUD9   24
CLJ                   Z-AXIS.  CLOUDS ARE NORMALLY ORIENTED WITH        CLOUD9   25
CLJ                   (+A)-AXIS EASTWARD (PSI=0.)    DEGREES            CLOUD9   26
CLJ      PARAMS COMMON                                                  CLOUD9   27
CLJ             DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS         CLOUD9   28
CLJ              RE = EARTH'S RADIUS, KM                                CLOUD9   29
CLJ   OUTPUT PARAMETERS                                                 CLOUD9   30
CLJ      ARGUMENT LIST (FOR ENTRY CLD E TO C)                           CLOUD9   31
CLJ            EC1, = CLOUD-K CENTERED CARTESIAN COORDINATES, KM        CLOUD9   32
CLJ            EC2, AND EC3                                             CLOUD9   33
CLJ      ARGUMENT LIST (FOR ENTRY CLD C TO E)                           CLOUD9   34
CLJ           RTP1, = GEOGRAPHIC POLAR COORDINATES (RTP1=RADIUS, KM.    CLOUD9   35
CLJ           RTP2,      RTP2=POLAR ANGLE (COLATITUDE), DEG.            CLOUD9   36
CLJ           RTP3       RTP3=AZIMUTHAL ANGLE (EAST LONGITUDE), DEG.)   CLOUD9   37
      COMMON/CLOUD/ NCLOUD,                                             CLOUD     2
     1   HCLOUD(20),THETCD(20),PHICD (20),CLOUDA( 20),CLOUDB(20),       CLOUD     3
     2   CLOUDC(20),CLDPSI(20),KCLOUD(20)                               CLOUD     4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
      DIMENSION  DA(3,3), XYZ(3)                                        CLOUD9   40
      EQUIVALENCE (DR,DTR),(REARTH,RE)                                  CLOUD9   41
CLJ                                                                     CLOUD9   42
CLJ      ENTRY CLD E TO C CONVERTS FROM GEOGRAPHIC POLAR COORDINATES    CLOUD9   43
CLJ      (RTP(1,2,3) IN THE ARGUMENT LIST) TO CLOUD-CENTERED CARTESIAN  CLOUD9   44
CLJ      COORDINATES (EC(1,2,3) IN THE ARGUMENT LIST).                  CLOUD9   45
CLJ                                                                     CLOUD9   46
      ENTRY CLD E TO C                                                  CLOUD9   47
C                                                                       CLOUD9   48
      IFLAG = 1                                                         CLOUD9   49
C                                                                       CLOUD9   50
C***** DEFINE (X,Y,Z) EARTH CENTERED COORDINATES                        CLOUD9   51
C                                                                       CLOUD9   52
      CALL POL TO CT ( RTP1,RTP2,RTP3,X,Y,Z )                           CLOUD9   53
C                                                                       CLOUD9   54
      XYZ(1) =  X                                                       CLOUD9   55
      XYZ(2) =  Y                                                       CLOUD9   56
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      XYZ(3) =  Z
C
C***** SET UP MATRIX DA( 3 BY 3 )
      SINPHI = SIN( DR*PHICD(K) )
      COSPHI = COS( DR*PHICD(K) )
      SINTHE = SIN( DR*THETCD(K) )
      COSTHE = COS( DR*THETCD(K) )
      DA(1,1) = -SINPHI
      DA(2,1) = -COSTHE*COSPHI
      DA(3,1) =  SINTHE*COSPHI
      DA(1,2) =  COSPHI
      DA(2,2) = -COSTHE*SINPHI
      DA(3,2) =  SINTHE*SINPHI
      DA(1,3) =  0.0
      DA(2,3) =  SINTHE
      DA(3,3) =  COSTHE
C
C***** CALCULATE FINAL CLOUD CENTERED COORDINATE SYSTEM
    1 CONTINUE
      X=0. $ Y=0. $ Z=0.
      DO 11 J=1,3
      X = X + DA(1,J)*XYZ(J)
      Y = Y + DA(2,J)*XYZ(J)
   11 Z = Z + DA(3,J)*XYZ(J)
C
      IF( IFLAG .EQ. 2 ) GO TO 14
      EC1   = X*COS( DR*CLDPSI(K) ) + Y*SIN( DR*CLDPSI(K) )
      EC2   = Y*COS( DR*CLDPSI(K) ) - X*SIN( DR*CLDPSI(K) )
      EC3   = Z - ( REARTH + HCLOUD(K) )
      RETURN
C
   14 CALL CT TO POL(RTP1,RTP2,RTP3,X,Y,Z)
C
      RETURN
CLJ
CLJ        ENTRY CLD C TO E CONVERTS FROM CLOUD-CENTERED CARTESIAN
CLJ        COORDINATES (EC(1,2,3) IN THE ARGUMENT LIST) TO GEOGRAPHIC
CLJ        POLAR COORDINATES (RTP(1,2,3) IN THE ARGUMENT LIST).
CLJ
      ENTRY CLD C TO E
C
      IFLAG = 2
C
      XYZ(1) = EC1*COS( DR*CLDPSI(K) ) - EC2*SIN( DR*CLDPSI(K) )
      XYZ(2) = EC1*SIN( DR*CLDPSI(K) ) + EC2*COS( DR*CLDPSI(K) )
      XYZ(3) = EC3 + ( RE + HCLOUD(K) )
C
C      TRANSPOSE MATRIX
      SINPHI = SIN( DR*PHICD(K) )
      COSPHI = COS( DR*PHICD(K) )
      SINTHE = SIN( DR*THETCD(K) )
      COSTHE = COS( DR*THETCD(K) )
      DA(1,1) = -SINPHI
      DA(1,2) = -COSTHE*COSPHI
      DA(1,3) =  SINTHE*COSPHI
      DA(2,1) =  COSPHI
      DA(2,2) = -COSTHE*SINPHI
      DA(2,3) =  SINTHE*SINPHI
      DA(3,1) =  0.0
      DA(3,2) =  SINTHE
      DA(3,3) =  COSTHE
C
CLJ        CALCULATE FINAL GEOGRAPHIC POLAR COORDINATES.
      GO TO 1
      END
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      SUBROUTINE CONVERT(R,TH,PH,X,Y,Z)                             CONVERT    2
CLJ                                                                 CONVERT    3
CLJ   SUBROUTINE CONVERT HAS TWO ENTRY POINTS.                      CONVERT    4
CLJ   ENTRY-(CT TO POL) CONVERTS FROM THE CARTESIAN COORDINATES (X,Y,Z) CONVERT    5
CLJ   TO THE POLAR COORDINATES (R,TH,PH).                           CONVERT    6
CLJ   ENTRY-(POL TO CT) CONVERTS FROM THE POLAR COORDINATES (R,TH,PH) CONVERT    7
CLJ   TO THE CARTESIAN COORDINATES (X,Y,Z).                         CONVERT    8
CLJ                                                                 CONVERT    9
CLJ   INPUT PARAMETERS                                              CONVERT   10
CLJ      ARGUMENT LIST (FOR ENTRY CT TO POL)                        CONVERT   11
CLJ             X, = CARTESIAN COORDINATES, USUALLY IN KM           CONVERT   12
CLJ             Y, AND Z                                            CONVERT   13
CLJ      ARGUMENT LIST (FOR ENTRY POL TO CT)                        CONVERT   14
CLJ              R = RADIUS, USUALLY IN KM                          CONVERT   15
CLJ             TH = POLAR ANGLE (COLATITUDE), DEG                  CONVERT   16
CLJ             PH = AZIMUTHAL ANGLE (EAST LONGITUDE), DEG          CONVERT   17
CLJ   OUTPUT PARAMETERS                                             CONVERT   18
CLJ      ARGUMENT LIST (FOR ENTRY CT TO POL)                        CONVERT   19
CLJ              R = RADIUS, SAME UNITS AS X,Y,Z                    CONVERT   20
CLJ             TH = POLAR ANGLE (COLATITUDE), DEG                  CONVERT   21
CLJ             PH = AZIMUTHAL ANGLE (EAST LONGITUDE), DEG          CONVERT   22
CLJ      ARGUMENT LIST (FOR ENTRY POL TO CT)                        CONVERT   23
CLJ             X, = CARTESIAN COORDINATES, SAME UNITS AS R         CONVERT   24
CLJ             Y,Z  (EARTH-CENTERED IF (R,TH,PH) ARE EARTH-CENTERED) CONVERT   25
CLJ                                                                 CONVERT   26
      DATA DTR,RTD  / .01745329251994,57.2957795131 /               CONVERT   27
CLJ                                                                 CONVERT   28
      ENTRY CT TO POL                                               CONVERT   29
CLJ                                                                 CONVERT   30
      R= SQRT( X**2 + Y**2 + Z**2 )                                 CONVERT   31
      TH= ACOS( Z/R)*RTD                                            CONVERT   32
      PH = ATAN2( Y,X )*RTD                                         CONVERT   33
      RETURN                                                        CONVERT   34
CLJ                                                                 CONVERT   35
      ENTRY POL TO CT                                               CONVERT   36
CLJ                                                                 CONVERT   37
      CT = COS( DTR*TH ) $ ST = SIN( DTR*TH )                       CONVERT   38
      CP = COS( DTR*PH ) $ SP = SIN( DTR*PH )                       CONVERT   39
      X= R*ST*CP                                                    CONVERT   40
      Y= R*ST*SP                                                    CONVERT   41
      Z= R*CT                                                       CONVERT   42
      RETURN                                                        CONVERT   43
      END                                                           CONVERT   44
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      SUBROUTINE DIFFUS(K,ALAM)                                         DIFFUS     2
CLJ                                                                     DIFFUS     3
CLJ   SUBROUTINE DIFFUS PROVIDES THE OUTGOING PHOTON FLUX (RADIANT       DIFFUS     4
CLJ   EMITTANCE) FROM A SURFACE ELEMENT ON AN ELLIPSOIDAL CLOUD         DIFFUS     5
CLJ   IRRADIATED BY A UNIT-STRENGTH, ISOTROPIC POINT SOURCE (BASED ON AN DIFFUS     6
CLJ   APPROXIMATE, ITERATIVE SOLUTION OF THE DIFFUSION EQUATION).       DIFFUS     7
CLJ                                                                     DIFFUS     8
CLJ   INPUT PARAMETERS                                                  DIFFUS     9
CLJ      ARGUMENT LIST                                                  DIFFUS    10
CLJ            K = CLOUD NUMBER                                         DIFFUS    11
CLJ         ALAM = WAVELENGTH, MICRONS                                  DIFFUS    12
CLJ      CDCORD COMMON                                                  DIFFUS    13
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        DIFFUS    14
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      DIFFUS    15
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        DIFFUS    16
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      DIFFUS    17
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        DIFFUS    18
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    DIFFUS    19
CLJ     CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE  DIFFUS    20
CLJ                   CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR DIFFUS    21
CLJ                   ELLIPSOIDAL CLOUD-K,  DEGREES    I=1,8     K=1,20 DIFFUS    22
CLJ    CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF  DIFFUS    23
CLJ                   THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE   DIFFUS    24
CLJ                   FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES          DIFFUS    25
CLJ                          J=1,16    K=1,20                           DIFFUS    26
CLJ   CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF    DIFFUS    27
CLJ                   SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM        DIFFUS    28
CLJ                      I=1,4      J=1,4      K=1,20                   DIFFUS    29
CLJ                   (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) DIFFUS    30
CLJ   CAREA(I,J,K) = AREA OF SURFACE FACET I,J IN PRINCIPAL OCTANT OF   DIFFUS    31
CLJ                   ELLIPSOIDAL CLOUD-K,  KM**2   I=1,4  J=1,4  K=1,20 DIFFUS    32
CLJ      CDDATA COMMON                                                  DIFFUS    33
CLJ          ALAMT(I) = WAVELENGTHS AT WHICH OPTICAL PROPERTIES ARE     DIFFUS    34
CLJ                     TABULATED, MICRONS                              DIFFUS    35
CLJ        SIGT(I,K) = TOTAL MICROSCOPIC EXTINCTION CROSS-SECTION AT    DIFFUS    36
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2 DIFFUS    37
CLJ        SIGS(I,K) = MICROSCOPIC SCATTERING CROSS-SECTION AT          DIFFUS    38
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2 DIFFUS    39
CLJ             W(I) = (NORMALIZED) CONTRIBUTION OF SPECULARLY-         DIFFUS    40
CLJ                     REFLECTED RADIATION TO SCATTERED RADIATION WITH DIFFUS    41
CLJ                     THE DIFFRACTED RADIATION CONTRIBUTING UNITY.    DIFFUS    42
CLJ                     USED ONLY FOR THE LARGE-PARTICLE-SIZE CLOUDS,   DIFFUS    43
CLJ                     TYPES 11 THROUGH 14.  (DIMENSIONLESS)           DIFFUS    44
CLJ      XMUBAR(I,K) = AVERAGE COSINE OF SCATTERING ANGLE AT            DIFFUS    45
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K            DIFFUS    46
CLJ           DNO(K) = NUMBER DENSITY OF WATER DROPLETS IN              DIFFUS    47
CLJ                     CLOUD-TYPE K, 1/CM**3                           DIFFUS    48
CLJ      CLOUD COMMON                                                   DIFFUS    49
CLJ       KCLOUD(K) = CLOUD-TYPE INDEX (1,14) FOR CLOUD K,  K=1,20      DIFFUS    50
CLJ      FLUX COMMON                                                    DIFFUS    51
CLJ        FIN(I,J) = 4.*PI TIMES THE INCOMING (NORMAL) PHOTON FLUX     DIFFUS    52
CLJ                   (IRRADIANCE) AT ELLIPSOIDAL-SURFACE FACET (I,J) AT DIFFUS    53
CLJ                   DISTANCE R FROM A UNIT STRENGTH, ISOTROPIC POINT  DIFFUS    54
CLJ                   SOURCE (I.E., (R DOT N)/R**3),    I=1,8    J=1,16 DIFFUS    55
CLJ                      4*PI*PHOTONS/(KM**2 SEC) FOR UNIT SOURCE       DIFFUS    56
CLJ      PARAMS COMMON                                                  DIFFUS    57
CLJ             PI = 3.14159265                                         DIFFUS    58
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CLJ   OUTPUT PARAMETER                                                  DIFFUS    59
CLJ      FLUX COMMON                                                    DIFFUS    60
CLJ        FOUT(I,J) = 4.*PI TIMES THE OUTGOING PHOTON FLUX (RADIANT    DIFFUS    61
CLJ                    EMITTANCE) FROM ELLIPSOIDAL-SURFACE FACET (I,J)  DIFFUS    62
CLJ                    FOR A UNIT STRENGTH, ISOTROPIC POINT SOURCE      DIFFUS    63
CLJ                    (ONE PHOTON PER SEC), (4.*PI*PHOTONS)/(KM**2 SEC) DIFFUS   64
CLJ                                                                     DIFFUS    65
      COMMON/CLOUD/ NCLOUD,                                             CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                              CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD     2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD     3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD     5
       DIMENSION SR(8,16),QR(8,16),F1(8,16)                             DIFFUS    69
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      COMMON/FLUX/  FIN(8,16),FOUT(8,16)                                FLUX       2
      DIMENSION  XIK(8,16),ETAK(8,16),ZETAK(8,16)                       DIFFUS    72
      DIMENSION  CXTRAP(11),XTRAP(11),CRELAX(29),RELAX(29)              DIFFUS    73
CLJ                                                                     DIFFUS    74
CLJ      XTRAP(CXTRAP(I)) AND RELAX(CRELAX(I)) ARE, RESPECTIVELY, THE   DIFFUS    75
CLJ      (DIMENSIONLESS) LINEAR EXTRAPOLATION LENGTHS AND RELAXATION    DIFFUS    76
CLJ      RATES, AT NXTRPC AND NRELXC VALUES CXTRAP(I) AND CRELAX(I) OF  DIFFUS    77
CLJ      THE PARAMETER C (RATIO OF SCATTERING TO TOTAL CROSS-SECTION),  DIFFUS    78
CLJ      TAKEN FROM TABLES 23 AND 9, RESPECTIVELY, OF INTRODUCTION TO   DIFFUS    79
CLJ      THE THEORY OF NEUTRON DIFFUSION, VOLUME 1, BY K.M. CASE,       DIFFUS    80
CLJ      F. DE HOFFMANN, AND G. PLACZEK, LASL, JUNE 1953.               DIFFUS    81
CLJ                                                                     DIFFUS    82
      DATA  NXTRPC,NRELXC / 11, 29 /                                    DIFFUS    83
      DATA  CXTRAP / 0.0    , 0.1    , 0.2    , 0.3    , 0.4    , 0.5    , DIFFUS 84
     1               0.6    , 0.7    , 0.8    , 0.9    , 1.0    /       DIFFUS    85
      DATA    XTRAP / 1.0000, 1.0000, 0.9993, 0.9889, 0.9606, 0.9201,   DIFFUS    86
     1               0.8750, 0.8300, 0.7871, 0.7472, 0.7104/            DIFFUS    87
      DATA CRELAX/0.00     ,0.10     ,0.20     ,0.30     ,0.35     ,0.40     , DIFFUS 88
     1           0.45     ,0.50     ,0.55     ,0.60     ,0.65     ,0.70     , DIFFUS 89
     2           0.75     ,0.80     ,0.82     ,0.84     ,0.86     ,0.88     , DIFFUS 90
     3           0.90     ,0.91     ,0.92     ,0.93     ,0.94     ,0.95     , DIFFUS 91
     4           0.96     ,0.97     ,0.98     ,0.99     ,1.00     /         DIFFUS 92
      DATA  RELAX/1.000000,1.000000,0.999909,0.997414,0.993164,0.985624, DIFFUS   93
     1           0.973976,0.957504,0.935529,0.907332,0.872065,0.828635, DIFFUS    94
     2           0.775516,0.710412,0.680241,0.647220,0.610884,0.570591, DIFFUS    95
     3           0.525430,0.500615,0.474002,0.445270,0.413976,0.379485, DIFFUS    96
     4           0.340829,0.296381,0.242983,0.172511,0.0     /          DIFFUS    97
CLJ      THE ARITHMETIC FUNCTION DIST(X1,Y1,Z1,X2,Y2,Z2) COMPUTES THE   DIFFUS    98
CLJ      DISTANCE BETWEEN THE POINTS (X1,Y1,Z1) AND (X2,Y2,Z2).         DIFFUS    99
      DIST(X1,Y1,Z1,X2,Y2,Z2) =SQRT((X2-X1)**2+(Y2-Y1)**2+(Z2-Z1)**2)   DIFFUS   100
C        EVALUATE THE CART COORD OF THE 128 AREAS IN THE K TH CLD       DIFFUS   101
      DO 10 I =.1,8                                                     DIFFUS   102
      IP  = IPRIME(I)                                                   DIFFUS   103
       DO 10 J = 1,16                                                   DIFFUS   104
      JP = IPRIME(J)                                                    DIFFUS   105
      CALL POL TO CT(CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),           DIFFUS   106
     X    XIK(I,J),ETAK(I,J),ZETAK(I,J) )                               DIFFUS   107
   10 CONTINUE                                                          DIFFUS   108
C                                                                       DIFFUS   109
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C       CALCULATE THE DIFFUSION PARAMETERS                              DIFFUS  110
C                                                                       DIFFUS  111
C       K IS THE CLOUD NO. INDEX                                        DIFFUS  112
C       KK IS THE TYPE INDEX FROM KCLOUD(K) TO GET AT                   DIFFUS  113
C       THE CLOUD PROPERTIES                                            DIFFUS  114
C                                                                       DIFFUS  115
      KK = KCLOUD(K)                                                    DIFFUS  116
       DO 20 I = 2,10                                                   DIFFUS  117
      IF(ALAMT(I) .GT. ALAM) GO TO 25                                   DIFFUS  118
   20 CONTINUE                                                          DIFFUS  119
      I = 10                                                            DIFFUS  120
   25 XX = ( ALAM - ALAMT(I-1) )/( ALAMT(I) - ALAMT(I-1) )              DIFFUS  121
      SGT= ( SIGT(I-1,KK) + ( SIGT(I,KK) - SIGT(I-1,KK) )*XX)*DNO(KK)*  DIFFUS  122
     X 1.E-3                                                            DIFFUS  123
      SGS= ( SIGS(I-1,KK) + ( SIGS(I,KK) - SIGS(I-1,KK) )*XX)*DNO(KK)   DIFFUS  124
     X *1.E-3                                                           DIFFUS  125
      WI = W(I-1) + ( W(I)-W(I-1) )*XX                                  DIFFUS  126
      IF( KK.GT.10 )  SGT = 2.*PI*RAD(KK)**2 * DNO(KK) * 1.0E-03        DIFFUS  127
      IF( KK.GT.10 )  SGS = 0.5*(1.+WI)*SGT                             DIFFUS  128
      XMU = XMUBAR(I-1,KK)+(XMUBAR(I,KK)-XMUBAR(I-1,KK) ) * XX          DIFFUS  129
CLJ     IN THE FOLLOWING EXPRESSIONS,                                   DIFFUS  130
CLJ           SGT = MACROSCOPIC TOTAL CROSS-SECTION, 1/KM               DIFFUS  131
CLJ           SGS = MACROSCOPIC SCATTERING CROSS-SECTION, 1/KM          DIFFUS  132
CLJ          SGTR = MACROSCOPIC TRANSPORT CROSS-SECTION, 1/KM           DIFFUS  133
CLJ           DDD = DIFFUSION COEFFICIENT, KM                           DIFFUS  134
CLJ            DA = 0.25 TIMES THE RATIO OF SCATTERING CROSS-SECTION    DIFFUS  135
CLJ                 TO TOTAL CROSS-SECTION FOR PHOTONS OF WAVELENGTH    DIFFUS  136
CLJ                 ALAM IN CLOUD-TYPE KK                               DIFFUS  137
CLJ     THE ABOVE DEFINITIONS FOR THE DIFFUSION PARAMETERS APPLY TO A   DIFFUS  138
CLJ     WEAKLY ABSORBING MEDIUM.  FOR A STRONGLY ABSORBING MEDIUM,      DIFFUS  139
CLJ     MODIFIED DIFFUSION PARAMETERS ARE REQUIRED.  WE ALSO COMPUTE    DIFFUS  140
CLJ     THE LATTER TYPE AND USE THEM AFTER 9/30/78.                     DIFFUS  141
      SGTR = SGT - XMU * SGS                                            DIFFUS  142
      GO TO 35                                                          DIFFUS  143
      DDD= SGS / (3.*SGT*SGTR)                                          DIFFUS  144
      DK = (SGT-SGS) / DDD                                              DIFFUS  145
CLJ             DK = INVERSE DIFFUSION LENGTH, 1/KM                     DIFFUS  146
      DK = SQRT(DK)                                                     DIFFUS  147
      DA = 0.25 * SGS / SGT                                             DIFFUS  148
      DB = DDD/2.                                                       DIFFUS  149
      WRITE(6,1010)  KK,DA,DB,DK                                        DIFFUS  150
 1010 FORMAT (*0  FOR CLOUD-TYPE K = *,I3,* THE STANDARD DIFFUSION PARAM DIFFUS  151
     1ETERS ARE DA,DB,DK = *,1P3E12.4)                                  DIFFUS  152
   35 CONTINUE                                                          DIFFUS  153
CLJ                                                                     DIFFUS  154
CLJ     WE NOW COMPUTE THE MODIFIED DIFFUSION PARAMETERS FOR AN         DIFFUS  155
CLJ     ABSORBING MEDIUM.                                               DIFFUS  156
CLJ                                                                     DIFFUS  157
      C = SGS/SGT                                                       DIFFUS  158
      CALL LINEAR( C,XTRAPC,CXTRAP,XTRAP,NXTRPC )                       DIFFUS  159
      CALL LINEAR( C,RELAXC,CRELAX,RELAX,NRELXC )                       DIFFUS  160
      DDD = (1.-C)/(RELAXC*RELAXC*SGTR)                                 DIFFUS  161
      DK = RELAXC*SQRT( SGT*SGTR )                                      DIFFUS  162
      DB = DDD/2.                                                       DIFFUS  163
      DA = DB*DK/(XTRAPC*RELAXC)                                        DIFFUS  164
      GO TO 37                                                          DIFFUS  165
      WRITE(6,1020)  KK,DA,DB,DK                                        DIFFUS  166
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 1020 FORMAT (*    FOR CLOUD-TYPE K = *,I3,* THE MODIFIED DIFFUSION PARAM DIFFUS   167
     1ETERS ARE DA,DB,DK = *,1P3E12.4)                                   DIFFUS   168
   37 CONTINUE                                                           DIFFUS   169
C                                                                        DIFFUS   170
C                                                                        DIFFUS   171
C                                                                        DIFFUS   172
CLJ       DO-200 LOOPS ARE OVER THE OUT-FACETS                           DIFFUS   173
      DO 200 IO = 1,8                                                    DIFFUS   174
      IOP = IPRIME(IO)                                                   DIFFUS   175
      DO 200 JO = 1,16                                                   DIFFUS   176
      JOP = IPRIME(JO)                                                   DIFFUS   177
      SR(IO,JO) = - FIN(IO,JO)                                           DIFFUS   178
      QR(IO,JO) = 1.                                                     DIFFUS   179
CLJ       DO-100 LOOPS ARE OVER THE IN-FACETS                            DIFFUS   180
      DO 100 II = 1,8                                                    DIFFUS   181
      IIP = IPRIME(II)                                                   DIFFUS   182
      DO 100 JI = 1,16                                                   DIFFUS   183
      JIP = IPRIME(JI)                                                   DIFFUS   184
      IF(IO .EQ. II  .AND.  JO .EQ. JI) GO TO 50                         DIFFUS   185
CLJ                R = DISTANCE BETWEEN IN-FACET AND OUT-FACET, KM       DIFFUS   186
      R = DIST(XIK(IO,JO),ETAK(IO,JO),ZETAK(IO,JO),                      DIFFUS   187
     1  XIK(II,JI),ETAK(II,JI),ZETAK(II,JI)  )                           DIFFUS   188
      GR = EXP(-DK*R) / R                                                DIFFUS   189
      EN DOT DG = GR *(DK + 1. / R)                                      DIFFUS   190
      CALL VSNORM(XIK(II,JI),ETAK(II,JI),ZETAK(II,JI),AN1,AN2,AN3,K)     DIFFUS   191
      EN DOT DG = EN DOT DG*(( XIK(IO,JO) - XIK(II,JI) )*AN1             DIFFUS   192
     1                  + (ETAK(IO,JO) - ETAK(II,JI) ) *AN2              DIFFUS   193
     X + ( ZETAK(IO,JO) - ZETAK(II,JI) )*AN3)/R                          DIFFUS   194
      FP = DA * GR + EN DOT DG * DDD/2.                                  DIFFUS   195
      FM =-DA * GR + EN DOT DG * DDD/2.                                  DIFFUS   196
      GO TO 90                                                           DIFFUS   197
C                                                                        DIFFUS   198
C        CALCULATE A LOCAL RADIUS OF CURVATURE                           DIFFUS   199
C        BASED UPON AN AVERAGE OF THE TWO RADII OF CURVATURE             DIFFUS   200
   50 RBARX = ( XIK(II,JI)/ASQ(K))**2 +                                  DIFFUS   201
     1          (ETAK(II,JI)/BSQ(K))**2 +                                DIFFUS   202
     1         (ZETAK(II,JI)/CSQ(K))**2                                  DIFFUS   203
      RBAR =   (RBARX -(  XIK(II,JI)/ASQ(K))**2)/ASQ(K)  +               DIFFUS   204
     1         (RBARX -(  ETAK(II,JI)/BSQ(K))**2)/BSQ(K)  +              DIFFUS   205
     2         (RBARX -( ZETAK(II,JI)/CSQ(K))**2)/CSQ(K)                 DIFFUS   206
CLJ        THE FINAL RBAR IS THE MEAN CURVATURE (I.E., ONE-HALF THE SUM  DIFFUS   207
CLJ        OF THE TWO PPINCIPAL CURVATURES).                             DIFFUS   208
      RBAR = 1. / (RBAR*ASQ(K)*BSQ(K)*CSQ(K)*SQRT(RBARX)*0.5)            DIFFUS   209
      GPC = 2.*SQRT(PI/CAREA(IIP,JIP,K))                                 DIFFUS   210
      FP = GPC *(  DA  -  DDD/2.*RBAR/2.)                                DIFFUS   211
      FM = GPC * (-DA  -  DDD/2.*RBAR/2.)                                DIFFUS   212
   90 CONTINUE                                                           DIFFUS   213
      SR(IO,JO) = SR(IO,JO) - FIN(II,JI)*FM*CAREA(IIP,JIP,K)/(PI*DDD)    DIFFUS   214
      QR(IO,JO) = QR(IO,JO) + FP*CAREA(IIP,JIP,K)/ ( PI * DDD)           DIFFUS   215
  100 CONTINUE                                                           DIFFUS   216
      FI(IO,JO) = SR(IO,JO) / QR(IO,JO)                                  DIFFUS   217
      FOUT(IO,JO) = FI(IO,JO)                                            DIFFUS   218
  200 CONTINUE                                                           DIFFUS   219
C        UNTIL A MORE SATISFACTORY SOLUTION CAN BE FOUND,                DIFFUS   220
C        WE WILL USE THE FIRST TERM IN THE NEUMANN SOLUTION              DIFFUS   221
      GO TO 210                                                          DIFFUS   222
      WRITE(6,4000) (J,(FIN (I,J),I=1,8),J=1,16)                         DIFFUS   223
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      WRITE(6,4000) (J,(SR  (I,J),I=1,8),J=1,16)                        DIFFUS    224
      WRITE(6,4000) (J,(QR  (I,J),I=1,8),J=1,16)                        DIFFUS    225
      WRITE(6,4000) (J,(FOUT(I,J),I=1,8),J=1,16)                        DIFFUS    226
 4000 FORMAT(1H0,I4,1P8E12.4/(1X,I4,1P8E12.4))                          DIFFUS    227
  210 CONTINUE                                                          DIFFUS    228
      RETURN                                                            DIFFUS    229
CLJ         HAVING OBTAINED THE FIRST-APPROXIMATION SOLUTION FOR THE    DIFFUS    230
CLJ         PHOTON FLUX, WE PROCEED TO OBTAIN THE SECOND-APPROXIMATION  DIFFUS    231
CLJ         SOLUTION.  MOST OF THE STEPS ARE A REPETITION OF THOSE ABOVE. DIFFUS  232
CLJ                                                                     DIFFUS    233
CLJ         DO-400 LOOPS ARE OVER THE OUT-FACETS                        DIFFUS    234
CLJ                                                                     DIFFUS    235
      DO 400 IO = 1,8                                                   DIFFUS    236
      IOP = IPRIME(IO)                                                  DIFFUS    237
      DO 400 JO = 1,16                                                  DIFFUS    238
      JOP = IPRIME(JO)                                                  DIFFUS    239
      FOUT(IO,JO) = F1(IO,JO)                                           DIFFUS    240
CLJ         DO-300 LOOPS ARE OVER THE IN-FACETS                         DIFFUS    241
      DO 300 II = 1,8                                                   DIFFUS    242
      IIP = IPRIME(II)                                                  DIFFUS    243
      DO 300 JI = 1,16                                                  DIFFUS    244
      IF(IO.EQ.II .AND. JO.EQ.JI) GO TO 300                             DIFFUS    245
      JIP = IPRIME(JI)                                                  DIFFUS    246
      R = DIST(XIK(IO,JO),ETAK(IO,JO),ZETAK(IO,JO),                     DIFFUS    247
     1   XIK(II,JI),ETAK(II,JI),ZETAK(II,JI)  )                         DIFFUS    248
      GR = EXP(-DK*R) / R                                               DIFFUS    249
      EN DOT DG = GR *(DK + 1. / R)                                     DIFFUS    250
      CALL VSNORM(XIK(II,JI),ETAK(II,JI),ZETAK(II,JI),AN1,AN2,AN3,K)    DIFFUS    251
      EN DOT DG = EN DOT DG*(( XIK(IO,JO) - XIK(II,JI) )*AN1            DIFFUS    252
     1                    + (ETAK(IO,JO) - ETAK(II,JI) ) *AN2           DIFFUS    253
     X + ( ZETAK(IO,JO) - ZETAK(II,JI) )*AN3)/R                         DIFFUS    254
      FP = DA * GR + EN DOT DG * DDD/2.                                 DIFFUS    255
      FM =-DA * GR + EN DOT DG * DDD/2.                                 DIFFUS    256
      FOUT(IO,JO) = FOUT(IO,JO) - (F1(II,JI) - F1(IO,JO)) *             DIFFUS    257
     X   FP*CAREA(IIP,JIP,K) / (PI*DDD*QR(IO,JO))                       DIFFUS    258
  300 CONTINUE                                                          DIFFUS    259
  400 CONTINUE                                                          DIFFUS    260
      RETURN                                                            DIFFUS    261
      END                                                               DIFFUS    262
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      SUBROUTINE DIFPRM(ALAM)                                           DIFPRM    2
C        ALAMT     WAVELENGTH TABLE  IN MICRONS                         DIFPRM    3
C       SIGT,SIGS,  MICROSCOPIC CROSS SECTIONS IN MICRONS SQUARED       DIFPRM    4
C        DNO       PARTICLE DENSITY IN  CM**-3                          DIFPRM    5
C                                                                       DIFPRM    6
C        DALFA,DBETA,DKAPPA   ARE DIFFUSION PARAMETERS                  DIFPRM    7
CCC                                                                     DIFPRM    8
CLJ   SUBROUTINE DIFPRM PROVIDES THREE DIFFUSION PARAMETERS FOR EACH    DIFPRM    9
CLJ   OF THE 14 CLOUD TYPES AT WAVELENGTH ALAM.                         DIFPRM   10
CCC                                                                     DIFPRM   11
CLJ   INPUT PARAMETERS                                                  DIFPRM   12
CLJ      ARGUMENT LIST                                                  DIFPRM   13
CLJ            ALAM = WAVELENGTH,  MICRONS                              DIFPRM   14
CLJ      CDDATA COMMON                                                  DIFPRM   15
CLJ           ALAMT(I)   = WAVELENGTHS AT WHICH OPTICAL PROPERTIES ARE  DIFPRM   16
CLJ                        TABULATED,  MICRONS                          DIFPRM   17
CLJ             SIGT(I,K) = TOTAL MICROSCOPIC EXTINCTION CROSS-SECTION  DIFPRM   18
CLJ                        AT WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K,     DIFPRM   19
CLJ                          (MICRONS)**2                               DIFPRM   20
CLJ             SIGS(I,K) = MICROSCOPIC SCATTERING CROSS-SECTION        DIFPRM   21
CLJ                        AT WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K,     DIFPRM   22
CLJ                          (MICRUNS)**2                               DIFPRM   23
CLJ                 W(I) = (NORMALIZED) CONTRIBUTION OF SPECULARLY-     DIFPRM   24
CLJ                     REFLECTED RADIATION TO SCATTERED RADIATION WITH DIFPRM   25
CLJ                     THE DIFFRACTED RADIATION CONTRIBUTING UNITY.    DIFPRM   26
CLJ                     USED ONLY FOR THE LARGE-PARTICLE-SIZE CLOUDS,   DIFPRM   27
CLJ                     TYPES 11 THROUGH 14.  (DIMENSIONLESS)           DIFPRM   28
CLJ          XMUBAR(I,K) = AVERAGE COSINE OF SCATTERING ANGLE AT        DIFPRM   29
CLJ                        WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K         DIFPRM   30
CLJ               DNO(K)   = NUMBER DENSITY OF WATER DROPLETS IN        DIFPRM   31
CLJ                        CLOUD-TYPE K,  1/CM**3                       DIFPRM   32
CLJ               RAD(K)   = MEAN RADIUS OF WATER DROPLETS IN           DIFPRM   33
CLJ                        CLOUD-TYPE K,  MICRONS                       DIFPRM   34
CCC                                                                     DIFPRM   35
CLJ                  FOR ABOVE VARIABLES   I=1,10  AND  K=1,14          DIFPRM   36
CCC                                                                     DIFPRM   37
CLJ   OUTPUT PARAMETERS                                                 DIFPRM   38
CLJ      DIFFUS COMMON                                                  DIFPRM   39
CLJ           DALFA(K) = 0.25 TIMES THE RATIO OF SCATTERING CROSS-      DIFPRM   40
CLJ                      SECTION TO TOTAL CROSS-SECTION FOR PHOTONS OF  DIFPRM   41
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K, DIMENSIONLESS DIFPRM   42
CLJ           DBETA(K) = 0.50 TIMES THE DIFFUSION COEFFICIENT FOR       DIFPRM   43
CLJ                      PHOTONS OF WAVELENGTH ALAM IN CLOUD-TYPE K,  KM DIFPRM  44
CLJ          DKAPPA(K) = INVERSE DIFFUSION LENGTH FOR PHOTONS OF        DIFPRM   45
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K,  1/KM         DIFPRM   46
CCC                                                                     DIFPRM   47
CLJ                  FOR ABOVE VARIABLES   K=1,14                       DIFPRM   48
CLJ      THE ABOVE DEFINITIONS FOR THE DIFFUSION PARAMETERS APPLY TO A  DIFPRM   49
CLJ      WEAKLY ABSORBING MEDIUM.  FOR A STRONGLY ABSORBING MEDIUM,     DIFPRM   50
CLJ      MODIFIED DIFFUSION PARAMETERS ARE REQUIRED.  WE ALSO COMPUTE   DIFPRM   51
CLJ      THE LATTER TYPE AND USE THEM AFTER 9/30/78.                    DIFPRM   52
CCC                                                                     DIFPRM   53
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA    2
     1 XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)             CDDATA    3
      COMMON/DIFFUS/DALFA(14),DBETA(14),DKAPPA(14)                      DIFCOM    2
      DIMENSION  CXTRAP(11),XTRAP(11),CRELAX(29),RELAX(29)              DIFPRM   57
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CLJ                                                                          DIFPRM   58
CLJ      XTRAP(CXTRAP(I)) AND RELAX(CRELAX(I)) ARE, RESPECTIVELY, THE        DIFPRM   59
CLJ      (DIMENSIONLESS) LINEAR EXTRAPULATION LENGTHS AND RELAXATION         DIFPRM   60
CLJ      RATES, AT NXTRPC AND NRELXC VALUES CXTRAP(I) AND CRELAX(I) OF       DIFPRM   61
CLJ      THE PARAMETER C (RATIO OF SCATTERING TO TOTAL CROSS-SECTION),       DIFPRM   62
CLJ      TAKEN FROM TABLES 23 AND 9, RESPECTIVELY, OF INTRODUCTION TO        DIFPRM   63
CLJ      THE THEORY OF NEUTRON DIFFUSION, VOLUME 1, BY K.M. CASE,            DIFPRM   64
CLJ      F. DE HOFFMANN, AND G. PLACZEK, LASL, JUNE 1953.                    DIFPRM   65
CLJ                                                                          DIFPRM   66
      DATA  NXTRPC,NRELXC / 11, 29 /                                         DIFPRM   67
      DATA  CXTRAP / 0.0    , 0.1    , 0.2    , 0.3    , 0.4    , 0.5    ,  DIFPRM   68
     1               0.6    , 0.7    , 0.8    , 0.9    , 1.0    /           DIFPRM   69
      DATA   XTRAP / 1.0000, 1.0000, 0.9993, 0.9889, 0.9606, 0.9201,        DIFPRM   70
     1               0.8750, 0.8300, 0.7871, 0.7472, 0.7104/                 DIFPRM   71
      DATA CRELAX/0.00     ,0.10     ,0.20     ,0.30    ,0.35    ,0.40    , DIFPRM   72
     1           0.45     ,0.50     ,0.55     ,0.60    ,0.65    ,0.70    ,  DIFPRM   73
     2           0.75     ,0.80     ,0.82     ,0.84    ,0.86    ,0.88    ,  DIFPRM   74
     3           0.90     ,0.91     ,0.92     ,0.93    ,0.94    ,0.95    ,  DIFPRM   75
     4           0.96     ,0.97     ,0.98     ,0.99    ,1.00    /           DIFPRM   76
      DATA  RELAX/1.000000,1.000000,0.999909,0.997414,0.993164,0.985624,   DIFPRM   77
     1           0.973976,0.957504,0.935529,0.907332,0.872065,0.828635,    DIFPRM   78
     2           0.775516,0.710412,0.680241,0.647220,0.610884,0.570591,    DIFPRM   79
     3           0.525430,0.500615,0.474002,0.445270,0.413976,0.379485,    DIFPRM   80
     4           0.340829,0.296381,0.242983,0.172511,0.0        /          DIFPRM   81
CLJ                                                                          DIFPRM   82
      COSH(ARG) = (EXP(ARG) + EXP(-ARG)) / 2.                                DIFPRM   83
      SINH(ARG) = (EXP(ARG) - EXP(-ARG)) / 2.                                DIFPRM   84
CLJ                                                                          DIFPRM   85
CLJ      TRANSMITTANCE T AND REFLECTANCE R OF PLANAR SLAB, PER               DIFPRM   86
CLJ      EQUATIONS (31A) AND (31B) OF APPENDIX A, NATURAL CLOUDS, THE        DIFPRM   87
CLJ      ROSCOE MANUAL VOL. 24.                                              DIFPRM   88
CLJ                                                                          DIFPRM   89
      T(X,Y) = 1.0 / ( COSH(X) + 0.5*( Y+1./Y )*SINH(X) )                    DIFPRM   90
      R(X,Y) = 0.5*T(X,Y)*( Y-1./Y )*SINH(X)                                 DIFPRM   91
CLJ                                                                          DIFPRM   92
      DO 20 I = 2,10                                                         DIFPRM   93
      IF (ALAMT(I) .GT. ALAM) GO TO 25                                       DIFPRM   94
   20 CONTINUE                                                               DIFPRM   95
      I = 10                                                                 DIFPRM   96
   25 XX = (ALAM - ALAMT(I-1)) / (ALAMT(I) - ALAMT(I-1))                     DIFPRM   97
C                                                                            DIFPRM   98
C                                                                            DIFPRM   99
C                                                                            DIFPRM  100
C       INTERPOLATE FOR DIFFUSION PARAMETERS AT GIVEN WAVELENGTH             DIFPRM  101
C       FOR ALL 14 CLOUD TYPES                                               DIFPRM  102
C                                                                            DIFPRM  103
      WI = W(I-1) + ( W(I)-W(I-1) )*XX                                       DIFPRM  104
      GO TO 111                                                              DIFPRM  105
CLJ                                                                          DIFPRM  106
CLJ      FOR EDUCATIONAL PURPOSES, THE TRANSMITTANCE T AND REFLECTANCE       DIFPRM  107
CLJ      R OF CLOUD-TYPE KK WITH THICKNESS CLDTHK(KK) ARE EVALUATED          DIFPRM  108
CLJ      FIRST FOR THE STANDARD DIFFUSION PARAMETERS AND THEN FOR THE        DIFPRM  109
CLJ      MODIFIED DIFFUSION PARAMETERS FOR AN ABSORBING MEDIUM.  THE         DIFPRM  110
CLJ      LATTER PARAMETERS HAVE BEEN USED SINCE 9/30/78.                     DIFPRM  111
CLJ                                                                          DIFPRM  112
      WRITE(6,110)                                                           DIFPRM  113
  110 FORMAT (2H1 ,*    KK      ALFA         BETA        KAPPA       CLDTHK  DIFPRM  114
```

```
     $               T             R      *)
 111 CONTINUE
     DO 30 KK = 1,14
     SGT = (SIGT(I-1,KK)+(SIGT(I,KK) - SIGT(I-1,KK))*XX)*DNO(KK)*1.E-3
     SGS = (SIGS(I-1,KK)+(SIGS(I,KK) - SIGS(I-1,KK))*XX)*DNO(KK)*1.E-3
     IF(KK .GT. 10) SGT = 2.*PI*RAD(KK)**2 * DNO(KK) * 1.E-3
     IF(KK .GT. 10)  SGS = 0.5*(1.+WI)*SGT
     XMU = XMUBAR(I-1,KK) + (XMUBAR(I,KK) - XMUBAR(I-1,KK))*XX
     SGTR = SGT - XMU * SGS
     GO TO 27
     DD = SGS / (3.*SGT*SGTR)
     DK = SQRT((SGT - SGS)/DD)
     DA = 0.25  * SGS / SGT
     DALFA(KK) = DA
     DBETA(KK) = DD/ 2.
     DKAPPA(KK) = DK
     X = DKAPPA(KK)*CLDTHK(KK)
     Y = DALFA(KK) / (DKAPPA(KK)*DBETA(KK))
     TKK = T(X,Y)
     RKK = R(X,Y)
     WRITE(6,120)  KK,DALFA(KK),DBETA(KK),DKAPPA(KK),CLDTHK(KK),TKK,RKK
 120 FORMAT (5X,I3,1P6E12.4)
  27 CONTINUE
CLJ
CLJ       WE NOW COMPUTE THE MODIFIED DIFFUSION PARAMETERS FOR AN
CLJ       ABSORBING MEDIUM.
CLJ
     C = SGS/SGT
     CALL LINEAR( C,XTRAPC,CXTRAP,XTRAP,NXTRPC )
     CALL LINEAR( C,RELAXC,CRELAX,RELAX,NRELXC )
     DD   = (1.-C)/(RELAXC*RELAXC*SGTR)
     DKAPPA(KK) = RELAXC*SQRT( SGT*SGTR )
     DBETA(KK) = DD/2.
     DALFA(KK) = DBETA(KK)*DKAPPA(KK)/(XTRAPC*RELAXC)
     GO TO 29
     X = DKAPPA(KK)*CLDTHK(KK)
     Y = DALFA(KK)/(DKAPPA(KK)*DBETA(KK))
     TKK = T(X,Y)
     RKK = R(X,Y)
     WRITE(6,120)  KK,DALFA(KK),DBETA(KK),DKAPPA(KK),CLDTHK(KK),TKK,RKK
  29 CONTINUE
  30 CONTINUE
     RETURN
     END
```

```
      FUNCTION DSURF(THETA,PHI,K)                                      DSURF    2
C EVALUATES ELLIPSOIDAL SURFACE ELEMENT AT THETA,PHI                   DSURF    3
C        (  INPUT ANGLES IN RADIANS  )                                 DSURF    4
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                 CDCORD   2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)    CDCORD   3
     X  , ASQ(20),BSQ(20),CSQ(20)                                      CDCORD   4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)        CDCORD   5
CCC                                                                    DSURF    6
CLJ   INPUT PARAMETERS                                                 DSURF    7
CLJ      ARGUMENT LIST                                                 DSURF    8
CLJ           THETA = POLAR ANGLE IN CLOUD-CENTERED COORDINATE SYSTEM  DSURF    9
CLJ                   AT WHICH FUNCTION DSURF IS TO BE EVALUATED, RADIAN DSURF  10
CLJ             PHI = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATE     DSURF   11
CLJ                   SYSTEM AT WHICH FUNCTION DSURF IS TO BE EVALUATED, DSURF  12
CLJ                   RADIANS                                          DSURF   13
CLJ               K = CLOUD-NUMBER INDEX                               DSURF   14
CLJ      CDCORD COMMON                                                 DSURF   15
CLJ         FOLLOWING PARAMETERS ARE SET IN SUBROUTINE CLDGEOM FOR     DSURF   16
CLJ         K=1,NCLOUD (.LE.20)                                        DSURF   17
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN       DSURF   18
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2     DSURF   19
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN       DSURF   20
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2     DSURF   21
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN       DSURF   22
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2   DSURF   23
CLJ   OUTPUT PARAMETER                                                 DSURF   24
CLJ      FUNCTION                                                      DSURF   25
CLJ           DSURF = FOR CLOUD K, THE PRODUCT OF SIN(THETA) AND THE   DSURF   26
CLJ                   ELLIPSOIDAL SURFACE AREA PER UNIT SOLID ANGLE IN DSURF   27
CLJ                   THE DIRECTION (THETA,PHI),  (SIN(THETA)*KM**2)/SR DSURF  28
CLJ                                                                    DSURF   29
      ST = SIN(THETA)                                                  DSURF   30
      CT = COS(THETA)                                                  DSURF   31
      SP = SIN(PHI)                                                    DSURF   32
      CP = COS(PHI)                                                    DSURF   33
      R = ST*ST*(CP*CP/ASQ(K)+SP*SP/BSQ(K))+CT*CT/CSQ(K)               DSURF   34
      RSQ = 1. / R                                                     DSURF   35
      S = RSQ * ST*CT*(CP*CP/ASQ(K)+SP*SP/BSQ(K) - 1./CSQ(K) )         DSURF   36
      T = RSQ*ST*SP*CP*  (1./ASQ(K) - 1. / BSQ(K) )                    DSURF   37
      DSURF=RSQ*ST*SQRT(1.0+S*S+T*T)                                   DSURF   38
      RETURN                                                           DSURF   39
      END                                                              DSURF   40
```

```
      FUNCTION EMISSF(ALAM,LL,MM,HH)                                    EMISSF     2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                           ATMOSX     2
      COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL                         SANDD      2
      COMMON /PARAMS/ IN,IOUT,PI,RF, DTR,RTD                            PARAMS     2
      INTEGER HH                                                        EMISSF     7
CCC                                                                     EMISSF     8
CLJ   FUNCTION EMISSF COMPUTES THE (ATTENUATED) SPECTRAL RADIANCE AT    EMISSF     9
CLJ   12-KM ALTITUDE FOR RADIATION EMITTED AT ZENITH ANGLE THETE FROM   EMISSF    10
CLJ   A CLOUD TOP AT ALTITUDE CLDTOP.   ( WATTS/(KM**2 SR MICRON) )     EMISSF    11
CCC                                                                     EMISSF    12
CLJ   INPUT PARAMETERS                                                  EMISSF    13
CLJ      ARGUMENT LIST                                                  EMISSF    14
CLJ            ALAM = WAVELENGTH,  MICRONS                              EMISSF    15
CLJ              LL = INDEX (1,7) OF ONE OF SEVEN LOW-ALTITUDE CLOUDS   EMISSF    16
CLJ                 = KCLOUD                                            EMISSF    17
CLJ              MM = INDEX (1,3) OF ONE OF THREE MID-ALTITUDE CLOUDS   EMISSF    18
CLJ                 = KCLOUD-7                                          EMISSF    19
CLJ              HH = INDEX (1,4) OF ONE OF FOUR HIGH-ALTITUDE CLOUDS   EMISSF    20
CLJ                 = KCLOUD-10                                         EMISSF    21
CLJ                 (KCLOUD = CLOUD-TYPE INDEX)                         EMISSF    22
CLJ      CDDATA COMMON                                                  EMISSF    23
CLJ         CLDBASE(K) = ALTITUDE ABOVE EARTH SURFACE OF BASE OF        EMISSF    24
CLJ                      CLOUD-TYPE K,   KM      K=1,14                 EMISSF    25
CLJ          CLDTHK(K) = THICKNESS OF CLOUD-TYPE K,  KM     K=1,14      EMISSF    26
CLJ      SANDD COMMON                                                   EMISSF    27
CLJ         UL,VL,WL = DETECTOR LOS DIRECTION COSINES                   EMISSF    28
CLJ         XD,YD,ZD = DETECTOR GEOCENTRIC CARTESIAN COORDINATES,  KM   EMISSF    29
CLJ         XS,YS,ZS = SOURCE GEOCENTRIC CARTESIAN COORDINATES,  KM     EMISSF    30
CLJ   OUTPUT PARAMETER                                                  EMISSF    31
CLJ      FUNCTION                                                       EMISSF    32
CLJ         EMISSF = THE (ATTENUATED) SPECTRAL RADIANCE AT 12-KM        EMISSF    33
CLJ                  ALTITUDE FOR RADIATION EMITTED AT ZENITH ANGLE     EMISSF    34
CLJ                  THETE FROM A CLOUD TOP AT ALTITUDE CLDTOP,         EMISSF    35
CLJ                  WATTS/(KM**2 SR MICRON)                            EMISSF    36
CLJ      DEFINITION OF MAIN VARIABLES                                   EMISSF    37
CLJ         RHOEPS(ALAM,CTHETE) = HEMISPHERICAL-DIRECTIONAL REFLECTANCE EMISSF    38
CLJ                               AT WAVELENGTH ALAM AND ZENITH ANGLE   EMISSF    39
CLJ                               ACOS(CTHETE) FOR CLOUD-TYPE 4         EMISSF    40
CLJ                               (STRATOCUMULUS)                       EMISSF    41
CLJ         ENN = DIRECTIONAL EMISSIVITY CORRESPONDING TO RHOEPS        EMISSF    42
CLJ             = 1.0-RHOEPS                                            EMISSF    43
CLJ         TAIR(ALAM,THETE,CLDTOP) = TRANSMITTANCE FOR RADIATION OF    EMISSF    44
CLJ                                   WAVELENGTH ALAM AT ZENITH ANGLE   EMISSF    45
CLJ                               THETE FROM ALTITUDE CLDTOP TO 12 KM   EMISSF    46
CCC                                                                     EMISSF    47
      IF(LL .LE. 7) N=LL                                                EMISSF    48
      IF(MM.LE. 3) N = MM + 7                                           EMISSF    49
      IF(HH .LE.4) N = HH + 10                                          EMISSF    50
      CLDTOP = CLDBASE(N) + CLDTHK(N)                                   EMISSF    51
      CALL SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,RD,SD,               EMISSF    52
     X   THETI,THETE,PHIE)                                              EMISSF    53
      TX = 1.0                                                          EMISSF    54
      IF( N.EQ.11 )  GO TO 10                                           EMISSF    55
      TX = TAIR(ALAM,THETE,CLDTOP)                                      EMISSF    56
   10 ENN = 1.0 - RHOEPS(ALAM,COS(THETE*DTR))                           EMISSF    57
      CALL ATMOSU(2,CLDTOP)                                             EMISSF    58
      T = TT                                                            EMISSF    59
      EMISSF = TX*1.191E14*ENN/ALAM**5 /(EXP(14388./(ALAM*T))- 1. )     EMISSF    60
      RETURN                                                            EMISSF    61
      END                                                               EMISSF    62
```

```
      SUBROUTINE ESURF(T1,T2,T3,T4,MSM,DD,T7,T8,T9,T10,T11,SFR,EPSD,TKS) ESURF   2
CC                                                                      ESURF   3
C       THIS IS A DUMMY ROUTINE REQUIRED IF THE CLOUD PACKAGE          ESURF   4
CC      IS EXERCISED AS A STAND-ALONE PROGRAM.                          ESURF   5
CC                                                                      ESURF   6
C       INPUT PARAMETERS(SELECTED)                                      ESURF   7
C           ARGUMENT LIST                                               ESURF   8
C             MSM = INDEX FOR CATEGORY OF SURFACE MATERIAL.             ESURF   9
C                 = 1, LAMBERTIAN DIFFUSE SURFACE WITH SPECTRALLY-      ESURF  10
C                      INDEPENDENT REFLECTANCE SET BY DD(1) AND         ESURF  11
C                      EMISSIVITY BY (1.-DD(1)).                        ESURF  12
C           DD(M) = ADDITIONAL DESCRIPTOR FOR SELECTED SURFACE          ESURF  13
C                   MATERIAL.                                           ESURF  14
C           FOR M = 1, (LAMBERTIAN SURFACE), DD(1) = DIFFUSE            ESURF  15
C                      REFLECTANCE. TYPICAL VALUE IS 0.10               ESURF  16
C       OUTPUT PARAMETERS                                               ESURF  17
C           ARGUMENT LIST                                               ESURF  18
C             SFR = FSUBR(M,DD(M),ZLAM'THI,THR,PSI)                     ESURF  19
C                 = BIDIRECTIONAL REFLECTANCE DISTRIBUTION              ESURF  20
C                   FUNCTION,  1./SR                                    ESURF  21
C            EPSD = 1.0 - RHOSUBM(ZLAM'THETA,2*PI)                      ESURF  22
C                 = DIRECTIONAL EMISSIVITY, DIMENSIONLESS.              ESURF  23
C             TKS = SURFACE TEMPERATURE, DEG K.                         ESURF  24
CC                                                                      ESURF  25
      DIMENSION  DD(7)                                                  ESURF  26
      DATA  PI / 3.14159265 /                                           ESURF  27
CC                                                                      ESURF  28
      SFR = DD(1)/PI                                                    ESURF  29
      EPSD = 1.0-DD(1)                                                  ESURF  30
      TKS = 288.                                                        ESURF  31
      RETURN                                                            ESURF  32
      END                                                               ESURF  33
```

```
            FUNCTION IPRIME(II)                                                 IP         2
            IPRIME     = AND( XOR( XOR(II-1,4)+1-II ,II-1), 3 ) + 1             IP         3
      CCC                                                                       IP         4
      CLJ      THE VALUES THAT IPRIME SHOULD RETURN ARE GIVEN IN SUBROUTINE     IP         5
      CLJ      CLDGEOM FOR II=1,16.                                             IP         6
      CLJ                                                                       IP         7
      CLJ    NOTE...                                                            IP         8
      CLJ                 USING THIS ROUTINE MAY GIVE ERRONEOUS RESULTS.        IP         9
      CCC                                                                       IP        10
      CLJ                 FOR CERTAIN VALUES OF THE INPUT VARIABLE II           IP        11
      CLJ                 A ONE'S COMPLEMENT MACHINE (CDC-6600, CDC-7600)       IP        12
      CLJ                 AND A TWO'S COMPLEMENT MACHINE (IBM-360, IBM-370)     IP        13
      CLJ                 DO NOT RETURN THE SAME VALUE FOR IPRIME.              IP        14
      CCC                                                                       IP        15
      CLJ                 A MACHINE INDEPENDENT SCHEME SHOULD BE USED.          IP        16
      CCC                                                                       IP        17
            RETURN                                                              IP        18
            END                                                                 IP        19
```

```
      SUBROUTINE LINEAR(XO,FXO,XX,FXX,NX)
CCC
C           GIVEN THE INDEPENDENT VARIABLE ARRAY, XX(I), AND THE
C           CORRESPONDING DEPENDENT VARIABLE ARRAY, FXX(I),
C           SUBROUTINE LINEAR WILL DO A LINEAR INTERPOLATION AND
C           RETURN FXO AT A GIVEN XO.
C
C           NX IS THE LENGTH OF THE ARRAYS XX AND FXX.
C
C           IF XO IS NOT WITHIN THE RANGE OF XX(I), FXO IS SET TO ZERO.
CCC
      DIMENSION XX(1), FXX(1)
      IF( XO .LT. XX(1) .OR. XO .GT. XX(NX) ) GO TO 22
      NX1 = 1
      NX3 = NX
      IF(NX.EQ.2) GO TO 6
    2 NX2 = (NX1 + NX3)/2
      IF( XO-XX(NX2) ) 4,18,10
    4 IF( NX2-NX1-1 ) 8,6,8
    6 NNX = NX1
      GO TO 16
    8 NX3 = NX2
      GO TO 2
   10 IF( NX3-NX2-1 ) 14,12,14
   12 NNX = NX2
      GO TO 16
   14 NX1 = NX2
      GO TO 2
   16 FXO = FXX(NNX) + ( XO-XX(NNX) )*( FXX(NNX+1)-FXX(NNX) )/
     X ( XX(NNX+1)-XX(NNX) )
      GO TO 20
   18 FXO = FXX(NX2)
   20 RETURN
   22 FXO = 0.0
      RETURN
      END
```

```
      SUBROUTINE LOS(K)                                                 LOSK   2
C                                                                       LOSK   3
C      TO BE CALLED FOP EACH CLOUD                                      LOSK   4
C                                                                       LOSK   5
CLJ                                                                     LOSK   6
CLJ   SUBROUTINE LOS COMPUTES THE DIRECTION COSINES, IN THE EARTH-      LOSK   7
CLJ   CENTERED CARTESIAN SYSTEM, OF A SELECTED SET OF LINE-OF-SIGHTS    LOSK   8
CLJ   FROM THE DETECTOR TO FACETS OF THE DETERMINISTIC CLOUDS.  THE     LOSK   9
CLJ   ALTITUDE AT WHICH EACH LOS INTERCEPTS A FACET IS ALSO COMPUTED.   LOSK  10
CLJ       THE SELECTED SET OF LINES-OF-SIGHT CONSISTS OF TWO SUBSETS.   LOSK  11
CLJ       THE FIRST SUBSET CONSISTS OF THOSE TO REFLECTIVE POINTS (I.E.,LOSK  12
CLJ       VISIBLE TO DETECTOR AND SOURCE), THE SECOND TO DIFFUSIVE      LOSK  13
CLJ       POINTS (VISIBLE TO DETECTOR BUT NOT TO SOURCE).  BY           LOSK  14
CLJ       CONSIDERING ONLY EVERY OTHER FACET, ONE HAS ONLY 32 (INSTEAD  LOSK  15
CLJ       OF 128) POINTS ON THE ELLIPSOID OF WHICH A MAXIMUM OF 16 ARE  LOSK  16
CLJ       VISIBLE TO THE DETECTOR.  ANY REFLECTIVE POINT THAT WOULD BE  LOSK  17
CLJ       LESS THAN 0.7*SQRT(FOV) FROM ANOTHER REFLECTIVE POINT IS      LOSK  18
CLJ       ELIMINATED.  DIFFUSIVE POINTS ARE LIMITED TO A MAXIMUM OF     LOSK  19
CLJ       EIGHT CLOSEST TO THE PERIMETER OF THE CLOUD.                  LOSK  20
CLJ                                                                     LOSK  21
CLJ   INPUT PARAMETERS                                                  LOSK  22
CLJ      ARGUMENT LIST                                                  LOSK  23
CLJ                K = DETERMINISTIC CLOUD NUMBER (SET IN DRIVER)       LOSK  24
CLJ      DETECT COMMON                                                  LOSK  25
CLJ               HD = ALTITUDE OF DETECTOR, KM                         LOSK  26
CLJ           THETAD = COLATITUDE OF DETECTOR, DEGREES                  LOSK  27
CLJ             PHID = EAST LONGITUDE OF DETECTOR, DEGREES              LOSK  28
CLJ              FOV = FIELD OF VIEW OF DETECTOR AT EARTH'S SURFACE,KM**2 LOSK  29
CLJ      CDCORD COMMON                                                  LOSK  30
CLJ         XI(I,K), = COORDINATES OF SOURCE-I IN K-TH CLOUD-CENTERED   LOSK  31
CLJ        ETA(I,K),   CARTESIAN SYSTEM, KM        I=1       K=1,20     LOSK  32
CLJ       ZETA(I,K)    (SET IN CLOUD1)                                  LOSK  33
CLJ          XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED   LOSK  34
CLJ         ETAD(K),   CARTESIAN SYSTEM, KM        K=1,20               LOSK  35
CLJ         ZETAD(K)   (SET IN CLOUD1)                                  LOSK  36
CLJ       CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE LOSK  37
CLJ                    CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR LOSK  38
CLJ                    ELLIPSOIDAL CLOUD-K,  DEGREES    I=1,8    K=1,20 LOSK  39
CLJ      CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF LOSK  40
CLJ                    THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE  LOSK  41
CLJ                    FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES         LOSK  42
CLJ                              J=1,16     K=1,20                      LOSK  43
CLJ      CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF LOSK  44
CLJ                    SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM       LOSK  45
CLJ                        I=1,4    J=1,4   K=1,20                      LOSK  46
CLJ                    (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) LOSK  47
CLJ      CLOUD COMMON                                                   LOSK  48
CLJ        HCLOUD(K) = ALTITUDE OF CLOUD-K CENTER ABOVE THE SURFACE, KM LOSK  49
CLJ                    K=1,NCLOUD    (READ IN CLOUD0)                   LOSK  50
CLJ   OUTPUT PARAMETERS                                                 LOSK  51
CLJ      LOS COMMON                                                     LOSK  52
CLJ        HLOS(1,L) = ALTITUDE AT WHICH LOS FROM DETECTOR INTERCEPTS   LOSK  53
CLJ                    L-TH FACET OF (IMPLICITLY) CLOUD-K, KM           LOSK  54
CLJ                    (1.LE.L.LE.16)                                   LOSK  55
CLJ       ULOS(1,L), = DIRECTION COSINES, IN EARTH-CENTERED CARTESIAN   LOSK  56
CLJ       VLOS(1,L),   SYSTEM, OF ABOVE-DESCRIBED LINES-OF-SIGHT.       LOSK  57
CLJ       WLOS(1,L)    FOR THESE VARIABLES, (1.LE.L.LE.16).  MAXIMUM    LOSK  58
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      CLJ              VALUE OF L DETERMINED BY INTERNAL SELECTION          LOSK      59
      CLJ              PROCESS ACCORDING TO SEVERAL CRITERIA.               LOSK      60
      CLJ                                                                   LOSK      61
            COMMON/CLOUD/ NCLOUD,                                           CLOUD      2
           1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),     CLOUD      3
           2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                            CLOUD      4
            COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                CDCORD     2
           1             XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD     3
           X  , ASQ(20),BSQ(20),CSQ(20)                                     CDCORD     4
           2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)       CDCORD     5
            COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                          PARAMS     2
            COMMON / DETECT/ HD, THETAD,PHID,FOV                            DET        2
            COMMON/ LOS /  HLOS(1,16), ULOS(1,16), VLOS(1,16), WLOS(1,16)   LOS        2
            DIMENSION IDISC(8,16),PSS(8,16),PDD(8,16)                       LOSK      67
            DIMENSION THSCAT(8,16),XX(8,16),YY(8,16),ZZ(8,16)               LOSK      68
            DIMENSION  THS(16),II(16),JJ(16),IS(16),JS(16)                  LOSK      69
      CLJ                                                                   LOSK      70
      CLJ      THE ARITHMETIC FUNCTION CTSCAT COMPUTES THE COSINE OF THE    LOSK      71
      CLJ      SCATTERING ANGLE OF A PHOTON MOVING FROM THE SOURCE AT POINT LOSK      72
      CLJ      (X1,Y1,Z1) TO THE CENTER OF AN ELLIPSOIDAL-SURFACE FACET AT  LOSK      73
      CLJ      POINT (X,Y,Z) AND THEN DIRECTLY TO THE DETECTOR AT POINT     LOSK      74
      CLJ      (X2,Y2,Z2).  COORDINATES ARE IN CLOUD-K CARTESIAN SYSTEM.    LOSK      75
      CLJ                                                                   LOSK      76
            CTSCAT( X,Y,Z,X1,Y1,Z1,X2,Y2,Z2 ) =                             LOSK      77
           1         ( (X-X1)*(X2-X) + (Y-Y1)*(Y2-Y) + (Z-Z1)*(Z2-Z) ) /    LOSK      78
           2      SQRT( ((X-X1)**2 + (Y-Y1)**2 + (Z-Z1)**2) *               LOSK      79
           3            ((X2-X)**2 + (Y2-Y)**2 + (Z2-Z)**2) )               LOSK      80
      C                                                                     LOSK      81
            CALL POL TO CT( HD+RE,THETAD,PHID,XD,YD,ZD )                    LOSK      82
            NS = 1                                                          LOSK      83
      CLJ                                                                   LOSK      84
      CLJ       LOOP OVER FACETS TO DETERMINE THEIR VISIBILITY TO DETECTOR  LOSK      85
      CLJ       AND TO SOURCE.                                              LOSK      86
      CLJ       WE HAVE ADOPTED J. GARBARINO'S SUGGESTION TO REDUCE THE NUMBER LOSK   87
      CLJ       OF FACETS EXAMINED BY CONSIDERING ONLY EVERY OTHER FACET.   LOSK      88
      CLJ       THIS RESULTS IN THE FOLLOWING (I,J) SETS FOR THE 32 POINTS... LOSK    89
      CLJ             1,1   1,3   ...   1,15                                LOSK      90
      CLJ             3,1   3,3   ...   3,15                                LOSK      91
      CLJ             5,1   5,3   ...   5,15                                LOSK      92
      CLJ             7,1   7,3   ...   7,15                                LOSK      93
      CLJ                                                                   LOSK      94
            DO 40 I=1,8,2                                                   LOSK      95
            IP= IPRIME(I)                                                   LOSK      96
            DO 40 J=1,16,2                                                  LOSK      97
            JP= IPRIME(J)                                                   LOSK      98
            P1= PS( XI(NS,K),ETA(NS,K),ZETA(NS,K),CTHBAR(I,K),CPHIBAR(J,K),K ) LOSK   99
            P2= PS( XID(K),ETAD(K),ZETAD(K),CTHBAR(I,K),CPHIBAR(J,K),K)     LOSK     100
      C                                                                     LOSK     101
            PSS(I,J)= P1                                                    LOSK     102
            PDD(I,J) = P2                                                   LOSK     103
      C                                                                     LOSK     104
            CALL POL TO CT( CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),        LOSK     105
           X XX(I,J),YY(I,J),ZZ(I,J) )                                      LOSK     106
      C                                                                     LOSK     107
      CLJ       DETERMINE COSINE OF SCATTERING ANGLE (AS DEFINED ABOVE).    LOSK     108
            THSCAT(I,J)=CTSCAT(XX(I,J),YY(I,J),ZZ(I,J),XI(NS,K),ETA(NS,K)   LOSK     109
           X    ,ZETA(NS,K),XID(K),ETAD(K),ZETAD(K)  )                      LOSK     110
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      IF( P1.GT. 0. .AND. P2 .GT. 0.) IDISC(I,J) = 1                   LOSK  111
      IF( P1.GT. 0. .AND. P2 .LT. 0.) IDISC(I,J) = 2                   LOSK  112
      IF( P1.LT. 0. .AND. P2 .GT. 0.) IDISC(I,J) = 3                   LOSK  113
      IF( P1.LT. 0. .AND. P2 .LT. 0.) IDISC(I,J) = 4                   LOSK  114
   40 CONTINUE                                                         LOSK  115
C                                                                      LOSK  116
C                                                                      LOSK  117
      DO 45 L=1,64                                                     LOSK  118
      HLOS(1,L) = 0.0                                                  LOSK  119
   45 CONTINUE                                                         LOSK  120
C                                                                      LOSK  121
C                                                                      LOSK  122
C                                                                      LOSK  123
C         ORDER THE POINTS                                             LOSK  124
CLJ       SORT THE FACET-CENTERS VISIBLE TO BOTH SOURCE AND DETECTOR IN LOSK 125
CLJ       ORDER OF INCREASING SCATTERING ANGLE.                        LOSK  126
C                                                                      LOSK  127
      L = 0                                                            LOSK  128
      DO 60 I=1,8,2                                                    LOSK  129
      DO 60 J=1,16,2                                                   LOSK  130
      IF(IDISC(I,J)  .NE. 1) GO TO 60                                  LOSK  131
      L = L + 1                                                        LOSK  132
      THS(L) = THSCAT(I,J)                                             LOSK  133
CLJ        ESTABLISH INDEX-ARRAYS FOR IDISC-1 POINTS.                  LOSK  134
      II(L) = I                                                        LOSK  135
      JJ(L) = J                                                        LOSK  136
   60 CONTINUE                                                         LOSK  137
      LL = 0                                                           LOSK  138
      IF(L .EQ. 0) GO TO 75                                            LOSK  139
CLJ       SORTING FROM HIGH TO LOW IN COSINE CORRESPONDS TO SORTING FROM LOSK 140
CLJ       LOW TO HIGH IN SCATTERING ANGLE.                             LOSK  141
      CALL SORTLJ(THS,II,JJ,L,+1)                                      LOSK  142
CLJ        THE FIRST CANDIDATE POINT IS AUTOMATICALLY MADE THE FIRST   LOSK  143
CLJ        SELECTED POINT.                                             LOSK  144
      LL = 1                                                           LOSK  145
CLJ        ABBREVIATE INDEXES OF FIRST SELECTED POINT TO AID IN GETTING LOSK 146
CLJ        ITS LOS VECTOR.                                             LOSK  147
      IC = II(LL)                                                      LOSK  148
      JC = JJ(LL)                                                      LOSK  149
CLJ        ESTABLISH INDEX-ARRAYS FOR SELECTED POINTS, IS(LL) AND JS(LL). LOSK 150
      IS(LL) = II(LL)                                                  LOSK  151
      JS(LL) = JJ(LL)                                                  LOSK  152
      CALL CLD C TO E(R,T,PH,XX(IC,JC),YY(IC,JC),ZZ(IC,JC),K)          LOSK  153
      CALL POL TO CT(R,T,PH,XC,YC,ZC)                                  LOSK  154
      RR = SQRT( (XD-XC)**2 + (YD-YC)**2 + (ZD-ZC)**2  )               LOSK  155
      HLOS(NS,LL) = R - RE                                             LOSK  156
      ULOS(NS,LL) = ( XC - XD ) / RR                                   LOSK  157
      VLOS(NS,LL) = ( YC - YD ) / RR                                   LOSK  158
      WLOS(NS,LL) = ( ZC - ZD ) / RR                                   LOSK  159
CLJ        CHECK REST OF CANDIDATE POINTS, FOR WHICH L= THEIR TOTAL NO. LOSK 160
      DO 70 I = 2,L                                                    LOSK  161
CLJ        ABBREVIATE INDEXES OF CANDIDATE POINT.                      LOSK  162
      IC = II(I)                                                       LOSK  163
      JC = JJ(I)                                                       LOSK  164
C                                                                      LOSK  165
C                                                                      LOSK  166
CLJ       FOR EACH NEW (TRIAL) LOS WITHIN THE SET SORTED WITH RESPECT TO LOSK 167
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CLJ      INCREASING SCATTERING ANGLE, FIND THE SEPARATION DISTANCE          LOSK
CLJ      (SEPAR),  MEASURED AT THE CLOUD AND NORMAL TO THE TRIAL LOS,       LOSK
CLJ      FROM EACH PREVIOUSLY SELECTED LOS.  THE TRIAL LOS IS REJECTED      LOSK
CLJ      IF SEPAR IS LESS THAN THE ADOPTED CRITERION FOR ANY PREVIOUSLY     LOSK
CLJ      SELECTED LOS.                                                      LOSK
CLJ       LL = NUMBER OF SELECTED POINTS.                                   LOSK
      DO 65 KK = 1,LL                                                       LOSK
CLJ       ABBREVIATE INDEXES OF THE SELECTED POINT BEING COMPARED WITH.     LOSK
      IL = IS(KK)                                                           LOSK
      JL = JS(KK)                                                           LOSK
CLJ       RDICJC = DISTANCE FROM DETECTOR TO CANDIDATE POINT (IC,JC)        LOSK
CLJ       RDILJL = DISTANCE FROM DETECTOR TO A SELECTED POINT (IL,JL)       LOSK
      RDICJC = SQRT( (XID(K)-XX(IC,JC))**2 + (ETAD(K)-YY(IC,JC))**2         LOSK
     $            + (ZETAD(K)-ZZ(IC,JC))**2 )                               LOSK
      RDILJL = SQRT( (XID(K)-XX(IL,JL))**2 + (ETAD(K)-YY(IL,JL))**2         LOSK
     $            + (ZETAD(K)-ZZ(IL,JL))**2 )                               LOSK
CLJ       DOT = COSINE OF ANGLE BETWEEN VECTORS FROM (1) DETECTOR TO        LOSK
CLJ       CANDIDATE POINT AND (2) DETECTOR TO A SELECTED POINT.             LOSK
      DOT = (                                                               LOSK
     X ( XID(K) - XX(IC,JC)) * ( XID(K) - XX(IL,JL)) +                      LOSK
     X ( ETAD(K) - YY(IC,JC)) * ( ETAD(K) - YY(IL,JL)) +                    LOSK
     X (ZETAD(K) - ZZ(IC,JC)) * (ZETAD(K) - ZZ(IL,JL)) )                    LOSK
     $  / (RDICJC*RDILJL)                                                   LOSK
      IF(DOT .GT. 1.0) DOT = 1.0                                            LOSK
      SEPAR = RDICJC * ACOS( DOT )                                          LOSK
      IF(SEPAR .LT. 0.7*SQRT(FOV) )  GO TO 70                               LOSK
   65 CONTINUE                                                              LOSK
C                                                                           LOSK
CLJ       CANDIDATE POINT HAS PASSED TEST.  INCREMENT SELECTED-POINT        LOSK
CLJ       INDEX LL AND ADD SUCCESSFUL-CANDIDATE INDEXES TO THOSE OF         LOSK
CLJ       SELECTED POINTS.  PROCEED TO OBTAIN LOS VECTOR OF NEWLY-          LOSK
CLJ       SELECTED POINT.                                                   LOSK
      LL = LL + 1                                                           LOSK
      IS(LL) = IC                                                           LOSK
      JS(LL) = JC                                                           LOSK
      CALL CLD C TO E(R,T,PH,XX(IC,JC),YY(IC,JC),ZZ(IC,JC),K)               LOSK
      HLOS(NS,LL) = R - RE                                                  LOSK
      CALL POL TO CT(R,T,PH,XC,YC,ZC)                                       LOSK
      RR = SQRT( (XD-XC)**2 + (YD-YC)**2 + (ZD-ZC)**2  )                    LOSK
      ULOS(NS,LL) = ( XC - XD ) / RR                                        LOSK
      VLOS(NS,LL) = ( YC - YD ) / RR                                        LOSK
      WLOS(NS,LL) = ( ZC - ZD ) / RR                                        LOSK
   70 CONTINUE                                                              LOSK
   75 CONTINUE                                                              LOSK
CLJ       SAVE THE NUMBER OF POINTS, LL1=LL, SELECTED FROM THOSE HAVING     LOSK
CLJ       IDISC=1.                                                          LOSK
      LL1 = LL                                                              LOSK
C                                                                           LOSK
CLJ      SORT THE FACET-CENTERS VISIBLE TO DETECTOR BUT NOT TO SOURCE IN    LOSK
CLJ      ORDER OF THEIR CLOSENESS TO THE TERMINATOR AS VIEWED FROM THE      LOSK
CLJ      DETECTOR.  FUNCTION PS IS POSITIVE FOR SUCH POINTS AND RANGES      LOSK
CLJ      FROM ZERO FOR A POINT ON THE TERMINATOR TO +1.0 FOR A POINT        LOSK
CLJ      WHOSE ELLIPSOIDAL-SURFACE NORMAL LIES ANTIPARALLEL TO THE LOS.     LOSK
      L = 0                                                                 LOSK
      DO 80 I=1,8,2                                                         LOSK
      DO 80 J=1,16,2                                                        LOSK
      IF(IDISC(I,J)  .NE. 3) GO TO 80                                       LOSK
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      L = L + 1                                                         LOSK  225
      THS (L) = PDD(I,J)                                                LOSK  226
CLJ      ESTABLISH INDEX-ARRAYS FOR IDISC-3 POINTS.                     LOSK  227
      II(L) = I                                                         LOSK  228
      JJ(L) = J                                                         LOSK  229
   80 CONTINUE                                                          LOSK  230
CLJ      SAVE THE NUMBER OF IDISC-3 POINTS, LL3=L.                      LOSK  231
      LL3 = L                                                           LOSK  232
      IF( L.EQ. 0) GO TO 95                                             LOSK  233
      CALL SORTLJ(THS,II,JJ,L,-1)                                       LOSK  234
CLJ      LIMIT THE DIFFUSIVE POINTS TO THOSE CLOSEST TO THE PERIMETER.  LOSK  235
CLJ      THIS LIMIT WOULD BE 16 IF 128 FACETS WERE CONSIDERED BUT IS    LOSK  236
CLJ      ONLY 8 IF 32 FACETS ARE CONSIDERED.                            LOSK  237
      LMAX1 = MIN0( L,8 )                                               LOSK  238
      DO 90 I = 1,LMAX1                                                 LOSK  239
CLJ      INCREMENT SELECTED-POINT INDEX LL, ABBREVIATE INDEXES OF       LOSK  240
CLJ      IDISC-3 POINT, AND PROCEED TO GET ITS LOS VECTOR.              LOSK  241
      LL = LL + 1                                                       LOSK  242
      IC = II(I)                                                        LOSK  243
      JC = JJ(I)                                                        LOSK  244
      CALL CLD C TO E(R,T,PH,XX(IC,JC),YY(IC,JC),ZZ(IC,JC),K)           LOSK  245
      HLOS(NS,LL) = R - RE                                              LOSK  246
      CALL POL TO CT(R,T,PH,XC,YC,ZC)                                   LOSK  247
      RR = SQRT( (XD-XC)**2 + (YD-YC)**2 + (ZD-ZC)**2  )                LOSK  248
      ULOS(NS,LL) = ( XC - XD ) / RR                                    LOSK  249
      VLOS(NS,LL) = ( YC - YD ) / RR                                    LOSK  250
      WLOS(NS,LL) = ( ZC - ZD ) / RR                                    LOSK  251
   90 CONTINUE                                                          LOSK  252
   95 CONTINUE                                                          LOSK  253
C                                                                       LOSK  254
      WRITE(6,1001) (L,ULOS(1,L),VLOS(1,L),WLOS(1,L),L=1,LL)            LOSK  255
 1001 FORMAT(* LOS  LL UVW*I3,1P3E20.12)                                LOSK  256
      WRITE(6,1002)  LL1                                                LOSK  257
 1002 FORMAT (44H0 NUMBER OF SELECTED LOS FOR IDISC=1 IS LL1=,I5)       LOSK  258
C                                                                       LOSK  259
      WRITE(6,1003)  LL3                                                LOSK  260
 1003 FORMAT (44H0 NUMBER OF SELECTED LOS FOR IDISC=3 IS LL3=,I5)       LOSK  261
      RETURN                                                            LOSK  262
       END                                                              LOSK  263
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            FUNCTION PS(X1,ET1,ZET1,THETA,PHI,K)                          PS          2
      CLJ                                                                 PS          3
      CLJ   FUNCTION PS IS A QUANTITY WHOSE SIGN DETERMINES THE VISIBILITY OF PS      4
      CLJ   A POINT (THETA,PHI) ON THE ELLIPSOIDAL CLOUD SURFACE FROM AN  PS          5
      CLJ   EXTERIOR POINT.                                               PS          6
      CLJ                                                                 PS          7
      CLJ   INPUT PARAMETERS                                              PS          8
      CLJ     ARGUMENT LIST                                               PS          9
      CLJ           X1, = COORDINATES OF AN EXTERIOR POINT (WHICH MAY BE  PS         10
      CLJ          ET1,   EITHER THE SOURCE OR THE DETECTOR) IN THE K-TH  PS         11
      CLJ         ZET1    CLOUD-CENTERED CARTESIAN COORDINATE SYSTEM,  KM PS         12
      CLJ                 NOTE. THE COORDINATES ARE XI(1,K), ETA(1,K),    PS         13
      CLJ                     ZETA(1,K) IF THE POINT IS AT THE SOURCE AND PS         14
      CLJ                     XID(K), ETAD(K), ZETA(K) IF AT THE DETECTOR. PS        15
      CLJ        THETA, = POLAR AND AZIMUTHAL COORDINATES OF A GIVEN FACET PS        16
      CLJ          PHI    CENTER ON CLOUD K                               PS         17
      CLJ             K = CLOUD NUMBER    K=1,20                          PS         18
      CLJ     CDCORD COMMON                                               PS         19
      CLJ       FOLLOWING PARAMETERS ARE SET IN SUBROUTINE CLDGEOM FOR    PS         20
      CLJ       K=1,10                                                    PS         21
      CLJ        ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN      PS         22
      CLJ                 HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2    PS         23
      CLJ        BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN      PS         24
      CLJ                 HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2    PS         25
      CLJ        CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN      PS         26
      CLJ                 VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2  PS         27
      CLJ     PARAMS COMMON                                               PS         28
      CLJ           DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS       PS         29
      CLJ   OUTPUT PARAMETER                                              PS         30
      CLJ     FUNCTION                                                    PS         31
      CLJ            PS = QUANTITY PROPORTIONAL TO THE DOT PRODUCT OF THE PS         32
      CLJ                 OUTWARD NORMAL AT THE POINT (THETA,PHI) AND THE PS         33
      CLJ                 VECTOR FROM THE POINT (THETA,PHI) TO THE EXTERIOR PS       34
      CLJ                 POINT.  THE CALLING SUBROUTINE (EITHER LOS OR   PS         35
      CLJ                 CLOUD3) DETERMINES THAT THE POINT IS VISIBLE IF PS         36
      CLJ                 PS IS POSITIVE AND HIDDEN IF PS IS ZERO OR      PS         37
      CLJ                 NEGATIVE.  (THE UNITS HAPPEN TO BE 1/KM, BUT    PS         38
      CLJ                      THAT IS UNIMPORTANT.)                      PS         39
      CLJ                                                                 PS         40
            COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),              CDCORD      2
           1          XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)      CDCORD      3
           X  , ASQ(20),BSQ(20),CSQ(20)                                   CDCORD      4
           2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)     CDCORD      5
            COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                        PARAMS      2
      C       IS THE POINT(THETA,PHI) ON THE ELLIPSOID SURFACE            PS         43
      C       VISIBLE TO THE POINT XI,ETA,ZETA                            PS         44
            ST = SIN(THETA*DTR)                                           PS         45
            CT = COS(THETA*DTR)                                           PS         46
            SP = SIN(PHI*DTR)                                             PS         47
            CP = COS(PHI*DTR)                                             PS         48
            R = 1. / SQRT(ST*ST*CP*CP/ASQ(K)+ST*ST*SP*SP/BSQ(K)+          PS         49
           1    CT*CT/CSQ(K))                                             PS         50
            PS = X1*ST*CP/ASQ(K) + ET1*ST*SP/BSQ(K) + ZET1*CT/CSQ(K) - 1./R PS       51
            RETURN                                                        PS         52
            END                                                           PS         53
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      FUNCTION RHOEPS(ALAM,CTHETA)
C
C        ALAM IS WAVELENGTH IN MICRONS
C        CTHETA IS COS(EXIT ANGLE)
C        RHOEPS IS DIRECTIONAL RHO
C        THE RHOTABLE COMES FROM CLOUD TYPE 4, I.E. CS
C        FOR 4 ANGLES AND 10 WAVELENGTHS
C
      DIMENSION TLAM(10),CTHET(4),RHO(4,10)
CCC
CLJ   FUNCTION RHOEPS COMPUTES THE HEMISPHERICAL-DIRECTIONAL
CLJ   REFLECTANCE FROM THE (HORIZONTAL) SURFACE OF CLOUD-TYPE 4
CLJ   (STRATOCUMULUS) FOR RADIATION OF WAVELENGTH ALAM REFLECTED INTO
CLJ   ZENITH ANGLE ACOS(CTHETA).
CCC
CLJ   INPUT PARAMETERS
CLJ      ARGUMENT LIST
CLJ            ALAM = WAVELENGTH,  MICRONS
CLJ          CTHETA = COSINE OF ZENITH ANGLE THETA
CLJ   OUTPUT PARAMETER
CLJ      FUNCTION
CLJ          RHOEPS = HEMISPHERICAL-DIRECTIONAL REFLECTANCE FOR
CLJ                   RADIATION OF WAVELENGTH ALAM REFLECTED AT ANGLE
CLJ                   THETA FROM THE NORMAL TO THE SURFACE OF A SEMI-
CLJ                   INFINITE SLAB OF CLOUD-TYPE 4 (STRATOCUMULUS)
CLJ   DEFINITION OF DATA
CLJ         RHO(I,N) = HEMISPHERICAL-DIRECTIONAL REFLECTANCE FOR
CLJ                    RADIATION OF WAVELENGTH TLAM(N) REFLECTED AT
CLJ                    ANGLE THETA(I)=ACOS(CTHET(I)) FROM THE NORMAL
CLJ                    TO THE SURFACE OF A SEMI-INFINITE SLAB OF
CLJ                    CLOUD-TYPE 4 (STRATOCUMULUS)
CLJ         THETA(I) = 0,30,60,90  DEGREES
CCC
CLJ               FOR ABOVE VARIABLES   I=1,4  AND  N=1,10
CCC
CLJ      VALUES OF RHO(I,N) ARE DERIVED FROM THE BIDIRECTIONAL
CLJ      REFLECTANCE DATA RFLN(J,K,I) IN FUNCTION CLDBDR BY THE
CLJ      (SCHEMATIC) FORMULA...
CCC
CLJ          RHO(I,N) = 2.*SUM( SUM( RFLN(J,K,I)*CTHOUT(J)*DELCTH(J)
CLJ                               *DELPHI(K) ) )  K=1,9  J=1,5
CLJ          CTHOUT(J) = 0.1 + 0.2*(J-1)   J=1,5
CLJ          DELCTH(J) = 0.20    J=1,5
CLJ          DELPHI(K) = PI/9.   K=1,9
CCC
CLJ          RHO(I,N) = (2.*PI/45.)*SUM( CTHOUT(J)*SUM( RFLN(J,K,I),
CLJ                     K=1,9 ), J=1,5 )
CCC
CLJ      THE MONTE CARLO RESULTS OBTAINED FOR AN INCIDENT ZENITH ANGLE
CLJ      OF 80 DEGREES ARE APPLIED HERE AT THETA(4)=90 DEGREES, A
CLJ      NECESSARY APPROXIMATION IN ORDER TO SPAN THE ENTIRE RANGE.
CCC
      DATA TLAM / 2.,2.5,2.55,2.65,2.75,2.85,3.2,3.5,4.,5. /
      DATA  CTHET / 1.00,0.866,0.500,0.0 /
      DATA RHO /
     *  .246738,  .337347,  .438561,  .582364,
     *  .263120,  .292961,  .408229,  .567398,
```

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     *    .164484,  .228606,  .344201,  .535932,                      RHOEPS   59
     *    .065790,  .114484,  .196950,  .405818,                      RHOEPS   60
     *    .003113,  .004874,  .019022,  .111126,                      RHOFPS   61
     *    .002738,  .003339,  .007853,  .041029,                      RHOEPS   62
     *    .008453,  .010461,  .019127,  .057703,                      RHOEPS   63
     *    .133816,  .159922,  .240649,  .372372,                      RHOFPS   64
     *    .207125,  .248432,  .362510,  .529662,                      RHOEPS   65
     *    .110265,  .136137,  .234503,  .413162                       RHOEPS   66
     X    /                                                           RHOEPS   67
C                                                                     RHOEPS   68
C         INTERPOLATION  -LINEAR IN BOTH WAVELENGTH AND COSINE OF ANGLE  RHOEPS   69
C                                                                     RHOEPS   70
      DO 10 II = 2,10                                                 RHOEPS   71
      I = II - 1                                                      RHOEPS   72
      IF(ALAM .LT. TLAM(II)) GO TO 15                                 RHOEPS   73
   10 CONTINUE                                                        RHOEPS   74
      I = 9                                                           RHOEPS   75
   15 CONTINUE                                                        RHOEPS   76
      DO 20 JJ = 2,4                                                  RHOEPS   77
      J = JJ - 1                                                      RHOEPS   78
      IF( CTHETA .GT. CTHET(JJ)) GO TO 25                             RHOEPS   79
   20 CONTINUE                                                        RHOEPS   80
      J = 3                                                           RHOEPS   81
   25 CONTINUE                                                        RHOEPS   82
      DEN = ( CTHETA-CTHET(J) )/( CTHET(J+1)-CTHET(J) )               RHOEPS   83
      A1 = RHO(J, I ) + (RHO(J+1, I )-RHO(J, I )) * DEN               RHOEPS   84
      A2 = RHO(J,I+1) + (RHO(J+1,I+1)-RHO(J,I+1)) * DEN               RHOEPS   85
      RHOEPS = A1 + ( A2-A1 )*( ALAM-TLAM(I) )/( TLAM(I+1)-TLAM(I) )  RHOEPS   86
      RETURN                                                          RHOEPS   87
      END                                                             RHOEPS   88
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      SUBROUTINE SCLOUD(ALAM,U,V,W,ISUN)                                SCLOUD   2
CLJ                                                                     SCLOUD   3
CLJ   SUBROUTINE SCLOUD, THE BASIC SUBROUTINE IN THE STATISTICAL-CLOUD  SCLOUD   4
CLJ   SUBMODEL, SERVES AS THE INTERMEDIARY BETWEEN THE DRIVER PROGRAM   SCLOUD   5
CLJ   AND ALL THE REMAINING ROUTINES IN THE STATISTICAL CLOUD SUBMODEL. SCLOUD   6
CLJ                                                                     SCLOUD   7
CLJ   INPUT PARAMETERS                                                  SCLOUD   8
CLJ      ARGUMENT LIST                                                  SCLOUD   9
CLJ            ALAM = WAVELENGTH, MICRONS                               SCLOUD  10
CLJ           U,V,W = DIRECTION COSINES IN EARTH-CENTERED CARTESIAN     SCLOUD  11
CLJ                   SYSTEM OF A USER-SPECIFIED LOS (SET IN DRIVER)    SCLOUD  12
CLJ            ISUN = FLAG TO DENOTE NATURE OF SOURCE                   SCLOUD  13
CLJ                 = 0  ARTIFICIAL SOURCE                              SCLOUD  14
CLJ                 = 1  SUN                                            SCLOUD  15
CLJ      CLDFREQ COMMON                                                 SCLOUD  16
CLJ         DEFINITIONS OF THE FOLLOWING THREE QUANTITIES ARE IN        SCLOUD  17
CLJ         THE BLOCK DATA ROUTINE.  KMODEL, CCOVER(ICC,KMODEL),        SCLOUD  18
CLJ         AND CFREQ(KCLOUD,ICC,KMODEL)                                SCLOUD  19
CLJ      CLDWT COMMON                                                   SCLOUD  20
CLJ         DEFINITIONS OF THE FOLLOWING FOUR QUANTITIES ARE IN         SCLOUD  21
CLJ         CLDWT ROUTINE.  IDX, WT(I), TRANS(I), AND EMISS(I)          SCLOUD  22
CLJ         WHERE  I=1,IDX-1                                            SCLOUD  23
CLJ      DETECT COMMON                                                  SCLOUD  24
CLJ              HD = ALTITUDE OF DETECTOR,  KM                         SCLOUD  25
CLJ          THETAD = COLATITUDE OF DETECTOR,  DEGREES                  SCLOUD  26
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               SCLOUD  27
CLJ      MATERL COMMON                                                  SCLOUD  28
CLJ             MSM = INDEX FOR CATEGORY OF SURFACE MATERIAL (SET IN    SCLOUD  29
CLJ                   DRIVER PROGRAM)                                   SCLOUD  30
CLJ                 = 1, LAMBERTIAN DIFFUSE SURFACE WITH SPECTRALLY-    SCLOUD  31
CLJ                      INDEPENDENT REFLECTANCE SET BY DD(1) AND       SCLOUD  32
CLJ                      EMISSIVITY BY (1.-DD(1)).                      SCLOUD  33
CLJ                 = 2, WATER            = 3, SNOW                     SCLOUD  34
CLJ                 = 4, SAND             = 5, SOIL                     SCLOUD  35
CLJ                 = 6, FOLIAGE          = 7, URBAN MATERIAL           SCLOUD  36
CLJ           DD(M) = ADDITIONAL DESCRIPTOR FOR SELECTED SURFACE        SCLOUD  37
CLJ                   MATERIAL (SET IN DRIVER PROGRAM)                  SCLOUD  38
CLJ         FOR M = 1, (LAMBERTIAN SURFACE), DD(1) = DIFFUSE            SCLOUD  39
CLJ                      REFLECTANCE. TYPICAL VALUE IS 0.10             SCLOUD  40
CLJ         FOR M = 2, (WATER), DD(2) = WIND SPEED, M/SEC.              SCLOUD  41
CLJ         FOR M = 3, (SNOW), DD(3) = SNOW-AGE PARAMETER,              SCLOUD  42
CLJ                      DD(3).GE.0. .AND. .LE.1.   VALUES OF 0. AND 1. SCLOUD  43
CLJ                      CORRESPOND TO NEW AND OLD SNOW RESPECTIVELY.   SCLOUD  44
CLJ         FOR M = 4,5,6,  DD(M) NOT USED.                             SCLOUD  45
CLJ         FOR M = 7, (URBAN MATERIAL), DD(7) = DEGREE-OF-URBANITY,    SCLOUD  46
CLJ                      DD(7).GE.0. .AND. .LE.1.   FOR DD(7) = 0., THE SCLOUD  47
CLJ                      SPECTRAL BRDF CORRESPONDS TO A FLAT SURFACE    SCLOUD  48
CLJ                      WITH AVERAGE DIRECTIONAL-REFLECTANCE PROPERTIES SCLOUD 49
CLJ                      OF CONCRETE AND ASPHALT. FOR DD(7) = 1., THE   SCLOUD  50
CLJ                      SPECTRAL BRDF CORRESPONDS TO A DIFFUSE         SCLOUD  51
CLJ                      REFLECTOR MULTIPLIED BY A SHADOW-FACTOR        SCLOUD  52
CLJ                      S(THI,THR) = ( COS(THI) + COS(THR) )/2.        SCLOUD  53
CLJ          SRFALT = ALTITUDE OF SURFACE, KM   (CURRENT FORMULATION OF SCLOUD  54
CLJ                   CLOUD MODEL REQUIRES THIS PARAMETER TO BE SET TO  SCLOUD  55
CLJ                   0.0)                                              SCLOUD  56
CLJ      PARAMS COMMON                                                  SCLOUD  57
CLJ              RE = EARTH'S RADIUS, KM                                SCLOUD  58
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CLJ          DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS           SCLOUD    59
CLJ   PTE COMMON                                                      SCLOUD    60
CLJ          P1, = PROBABILITY LEVELS (FRACTILES) AT WHICH TRANSFER   SCLOUD    61
CLJ          P2,   COEFFICIENTS AND EMISSION RADIANCES ARE DESIRED.   SCLOUD    62
CLJ         P3,P4  SET IN DRIVER PROGRAM.                             SCLOUD    63
CLJ   SOLARP COMMON                                                   SCLOUD    64
CLJ       SOLLAT = NORTH LATITUDE OF SUBSOLAR POINT (RADIANS)         SCLOUD    65
CLJ       SOLLON = EAST LONGITUDE OF SUBSOLAR POINT (RADIANS)         SCLOUD    66
CLJ   SORCE COMMON                                                    SCLOUD    67
CLJ    HSORCE(I) = ALTITUDE OF SOURCE-I ABOVE SURFACE,  KM            SCLOUD    68
CLJ    THETAS(I) = COLATITUDE OF SOURCE-I,  DEGREES                   SCLOUD    69
CLJ      PHIS(I) = EAST LONGITUDE OF SOURCE-I,  DEGREES               SCLOUD    70
CLJ    RSORCE(I) = RADIUS OF SOURCE-I,  KM                            SCLOUD    71
CLJ OUTPUT PARAMETERS                                                 SCLOUD    72
CLJ   FLAGS COMMON                                                    SCLOUD    73
CLJ       ITFLAG = 0  IF SUN IS BELOW THE HORIZON                     SCLOUD    74
CLJ              = 1  IF SUN IS ABOVE THE HORIZON                     SCLOUD    75
CLJ                   OR IF AN ARTIFICIAL SOURCE IS PRESENT           SCLOUD    76
CLJ   PTE COMMON                                                      SCLOUD    77
CLJ          T1, = TRANSFER COEFFICIENTS AT 12-KM ALTITUDE FOR        SCLOUD    78
CLJ          T2,   ARTIFICIAL POINT SOURCE, CORRESPONDING TO P1,P2,   SCLOUD    79
CLJ          T3,   P3,P4.  A TRANSFER COEFFICIENT IS THE RATIO OF A   SCLOUD    80
CLJ          T4    RADIANCE TO AN IRRADIANCE.  (1/SR)                 SCLOUD    81
CLJ          S1, = TRANSFER COEFFICIENTS AT 12-KM ALTITUDE FOR SUN AS SCLOUD    82
CLJ          S2,   A SOURCE, CORRESPONDING TO P1,P2,P3,P4.  (1/SR)    SCLOUD    83
CLJ         S3,S4                                                     SCLOUD    84
CLJ          E1, = THERMAL EMISSION (SPECTRAL RADIANCE) FROM TOP      SCLOUD    85
CLJ          E2,   LAYER OF CLOUDS OR THE GROUND (FOR THE CLOUD-FREE  SCLOUD    86
CLJ          E3,   LINE-OF-SIGHT), CORRESPONDING TO P1,P2,P3,P4.      SCLOUD    87
CLJ          E4    (WATTS/(KM**2 SR MICRON))                          SCLOUD    88
CLJ       PCFLOS = PROBABILITY OF THE DETECTOR SEEING THE ARTIFICIAL  SCLOUD    89
CLJ                SOURCE, EITHER WITH CLOUDS PRESENT (FOR WHICH WE   SCLOUD    90
CLJ                HAVE USED A POSTULATED ALTITUDE-DEPENDENT CFLOS    SCLOUD    91
CLJ                FUNCTION) OR WITHOUT CLOUDS BEING PRESENT.         SCLOUD    92
CLJ                A VALUE OF 0.0 IS RETURNED IF THE SOURCE IS NOT    SCLOUD    93
CLJ                WITHIN THE FIELD-OF-VIEW.                          SCLOUD    94
CLJ                                                                   SCLOUD    95
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)             CLDFREQ    2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                            DET        2
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                          PARAMS     2
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)     SORCE      2
      COMMON/CLDWT/IDX,WT(161),TRANS(161),EMISS(161)                  CLDWGT     2
      COMMON/FLAGS/ ITFLAG                                            FLAGS      2
      COMMON /MATERL/MSM,DDM(7),SRFALT                                MATERL     2
      COMMON/ PTE /  P1,P2,P3,P4,T1,T2,T3,T4,                         PTE        2
     1               S1,S2,S3,S4,E1,E2,E3,E4                          PTE        3
     1               ,PCFLOS                                          PTE        4
      COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL                       SANDD      2
      COMMON/SOLARP/ SOLLAT,SOLLON,DUMDUM(10)                         SOLARC     2
      DIMENSION WT1(161)                                              SCLOUD   106
      LOGICAL SPCULR,ESURF1                                           SCLOUD   107
      DATA  RSUN / 1.495979E+08 /                                     SCLOUD   108
CLJ      THE ARITHMETIC FUNCTION PLANK PROVIDES SPECTRAL RADIANCE AT  SCLOUD   109
CLJ      WAVELENGTH AA(MICRONS) AND TEMPERATURE TT(DEG KELVIN),       SCLOUD   110
CLJ      WATTS/(KM**2 SR MICRON))                                     SCLOUD   111
      PLANK(AA,TT) = 1.191E14/(AA**5*(EXP(14388./(AA*TT))-1.))        SCLOUD   112
CLJ      THE ARITHMETIC FUNCTIONS CFLOSC AND CFLOSH RESULT FROM OUR   SCLOUD   113
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CLJ        POSTULATING A SIMPLE ALTITUDE-DEPENDENCE TO THE CFLOS                SCLOUD   114
CLJ        FUNCTIONS FOR THE RESPECTIVE PATHS FROM (A) THE ARTIFICIAL           SCLOUD   115
CLJ        SOURCE TO THE GROUND AND (B) THE ARTIFICIAL SOURCE TO THE            SCLOUD   116
CLJ        DETECTOR.  THE ALTITUDE-DEPENDENT FACTOR F IS DEFINED IN THE         SCLOUD   117
CLJ        ROUTINE BEFORE USING THESE ARITHMETIC FUNCTIONS.                     SCLOUD   118
CLJ                                                                             SCLOUD   119
      CFLOSG( KQ,QA,QF ) = 1.0 - ( QF * (1.0-CFLOSF( KQ,QA ) ) )                SCLOUD   120
      CFLOSH( KQ,QA,QF ) = QF + (1.0-QF) * CFLOSF( KQ,QA )                      SCLOUD   121
CLJ                                                                             SCLOUD   122
      UL = U                                                                    SCLOUD   123
      VL = V                                                                    SCLOUD   124
      WL = W                                                                    SCLOUD   125
C                                                                               SCLOUD   126
      NS = 1                                                                    SCLOUD   127
      ALT = HSORCE(NS)                                                          SCLOUD   128
      IF( ISUN.EQ.0 )  CALL POL TO CT(ALT+RE,THETAS(NS),PHIS(NS),               SCLOUD   129
     $ XS,YS,ZS)                                                                SCLOUD   130
      IF( ISUN.EQ.1 )  CALL POL TO CT(RSUN,90.-SOLLAT*RTD,SOLLON*RTD,           SCLOUD   131
     $ XS,YS,ZS)                                                                SCLOUD   132
      HSAVE = HSORCE(1)                                                         SCLOUD   133
      IF( ISUN.EQ.1 )  HSORCE(1) = RSUN-RE                                      SCLOUD   134
      CALL POL TO CT(HD+RE,THETAD,PHID,XD,YD,ZD)                                SCLOUD   135
C                                                                               SCLOUD   136
CLJ        THIS CALL TO SGEOM GETS (1) THE ANGLE THI USED TO TEST WHETHER       SCLOUD   137
CLJ        OR NOT THE SUN IS ABOVE THE HORIZON AND (2) THE LOS ZENITH           SCLOUD   138
CLJ        ANGLE THR FOR USE BY SUBROUTINE CLDWT IN CALLING CFLOSF.  THE        SCLOUD   139
CLJ        ANGLE THR AND THE AZIMUTHAL ANGLE PSI ARE ALSO USED IN CALLING       SCLOUD   140
CLJ        SUBROUTINE ESURF, AND THE ANGLE THI MAY ALSO BE USED IN THAT         SCLOUD   141
CLJ        CALL.  HOWEVER, IF THE SOURCE IS AN ARTIFICIAL ONE AND ITS           SCLOUD   142
CLJ        ALTITUDE IS LESS THAN THE RADIUS ASSIGNED TO THE FINITE-S+OE         SCLOUD   143
CLJ        SOURCE, IT IS THEN NECESSARY TO RESET THE ANGLE THI WITH             SCLOUD   144
CLJ        ANOTHER CALL TO SUBROUTINE SGEOM BEFORE CALLING SUBROUTINE           SCLOUD   145
CLJ        ESURF.                                                               SCLOUD   146
      CALL SGEOM(UL,VL,WL,SRFALT,XD,YD,ZD,XS,YS,ZS,                             SCLOUD   147
     X     RDIST,SDIST,THI,THR,PSI)                                             SCLOUD   148
CC                                                                              SCLOUD   149
      IDAY = 1                                                                  SCLOUD   150
      IF( THI.GT.90. )  IDAY = 0                                                SCLOUD   151
      ITFLAG = 1                                                                SCLOUD   152
      IF( IDAY.EQ.0 .AND. ISUN.EQ.1 )  ITFLAG = 0                               SCLOUD   153
C        CALL DIFPRM TO GET DIFFUSION PARAMETERS                                SCLOUD   154
C        FOR GIVEN WAVELENGTH FOR ALL 14 CLOUDS                                 SCLOUD   155
      CALL DIFPRM(ALAM)                                                         SCLOUD   156
      CALL CLDWT(ALAM,THP)                                                      SCLOUD   157
      II = IDX                                                                  SCLOUD   158
C     GET ESURF PARAMETERS                                                      SCLOUD   159
      ZLAM = ALAM                                                               SCLOUD   160
      ZKM = SRFALT                                                              SCLOUD   161
      IFIRES = 0.                                                               SCLOUD   162
      SPCULR =  .FALSE.                                                         SCLOUD   163
      ESURFI = .TRUE.                                                           SCLOUD   164
CLJ        RESET THI TO THIEFF AND SDIST TO SDEFF IF ISUN=0 AND                 SCLOUD   165
CLJ        IF HSURCE(1) .LT. RSORCE(1).                                         SCLOUD   166
      IF( (ISUN.EQ.1) .OR. (ALT.GE.RSORCE(1)) )  GO TO 2                        SCLOUD   167
      HSEFF = 0.5*(ALT + RSORCE(1))                                             SCLOUD   168
      CALL POL TO CT(RE+HSEFF,THETAS(NS),PHIS(NS),XSEFF,YSEFF,ZSEFF)            SCLOUD   169
      CALL SGEOM(UL,VL,WL,SRFALT,XD,YD,ZD,XSEFF,YSEFF,ZSEFF,                    SCLOUD   170
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     $              RDEFF,SDEFF,THIEFF,THR,PSI)                         SCLOUD   171
      SDIST = SDEFF                                                     SCLOUD   172
      THI = THIEFF                                                      SCLOUD   173
CLJ       FOR LATER USE, SAVE AND SET...                                SCLOUD   174
      HSAVE2 = HSORCE(1)                                                SCLOUD   175
      HSORCE(1) = HSEFF                                                 SCLOUD   176
    2 CONTINUE                                                          SCLOUD   177
      CALL ESURF(THI*DTR,THR*DTR,PSI*DTR,ZKM,MSM,DDM(1),                SCLOUD   178
     X  SPCULR,ZLAM,IDAY,IFIRES,ESURF1,SFR,EPSD,TKS  )                  SCLOUD   179
      T2TP = TAIR(ALAM,THR,ZKM)                                         SCLOUD   180
      EMISS(II) = EPSD * PLANK(ALAM,TKS) * T2TP                         SCLOUD   181
      IF( ITFLAG.EQ.0 )  GO TO 4                                        SCLOUD   182
CLJ       WE NOW DEVELOP THE WEIGHT TO BE USED IN RESETTING WT(II) TO   SCLOUD   183
CLJ       ACCOUNT FOR THE TWO-LEG CFLUS NEEDED TO VIEW THE SOURCE-LIT   SCLOUD   184
CLJ       GROUND.                                                       SCLOUD   185
CLJ       IF THE ARTIFICIAL SOURCE WERE ABOVE THE TOP OF THE HIGHEST    SCLOUD   186
CLJ       CLOUD TOP IN THE STATISTICAL MODEL (I.E., ABOVE 12-KM         SCLOUD   187
CLJ       ALTITUDE), THE PROBABILITY OF THE DETECTOR SEEING THE SOURCE- SCLOUD   188
CLJ       LIT GROUND WOULD BE THE SAME AS THAT FOR THE SUN.  IF THE     SCLOUD   189
CLJ       ARTIFICIAL SOURCE WERE BELOW SUCH AN ALTITUDE, THEN IT IS     SCLOUD   190
CLJ       LIKELY THAT THE VALUE OF AN APPROPRIATE CFLOSF(ICC,THI)       SCLOUD   191
CLJ       WOULD BE LARGER THAN THAT FOR THE SUN, WITH THE EXACT AMOUNT  SCLOUD   192
CLJ       DEPENDING ON THE ALTITUDE.  SUCH A DATA BASE IS NOT READILY   SCLOUD   193
CLJ       AVAILABLE (IF IT EXISTS AT ALL), SO WE SHALL USE AN           SCLOUD   194
CLJ       APPROXIMATION.  DEFINE THE FACTOR F...                        SCLOUD   195
      F = 1.0                                                           SCLOUD   196
      IF( HSORCE(1).LT.12. )  F = 1. - (12. - HSORCE(1)) / 11.85        SCLOUD   197
      IF( HSORCE(1).LT.0.15)  F = 0.                                    SCLOUD   198
CLJ       THEN THE POSTULATED CFLOS-FUNCTION FOR THE DOWNWARD LEG IS    SCLOUD   199
CLJ       GIVEN BY THE ARITHMETIC FUNCTION CFLOSG(ICC,THI,F).           SCLOUD   200
CLJ       NOTE THAT IF F=1., THEN CFLOSG(ICC,THI,1.)=CFLOSF(ICC,THI).   SCLOUD   201
CLJ       THE PROBABILITY OF THE DETECTOR SEEING THE SOURCE-LIT GROUND  SCLOUD   202
CLJ       THROUGH THE CLOUDS IS SLGCLD, GIVEN BY...                     SCLOUD   203
      SLGCLD = CCOVER(2,KMODEL) * CFLOSF( 4,THR) * CFLOSG( 4,THI,F)     SCLOUD   204
     $       + CCOVER(3,KMODEL) * CFLOSF( 6,THR) * CFLOSG( 6,THI,F)     SCLOUD   205
     $       + CCOVER(4,KMODEL) * CFLOSF( 9,THR) * CFLOSG( 9,THI,F)     SCLOUD   206
     $       + CCOVER(5,KMODEL) * CFLOSF(11,THR) * CFLOSG(11,THI,F)     SCLOUD   207
CLJ       THE PROBABILITY OF SEEING THE SOURCE-LIT GROUND WITHOUT       SCLOUD   208
CLJ       CLOUDS IS (ESSENTIALLY) SLGCLR...                             SCLOUD   209
CLJ                                                                     SCLOUD   210
      SLGCLR = CCOVER(1,KMODEL)                                         SCLOUD   211
CLJ                                                                     SCLOUD   212
CLJ       WHICH SHOULD, IN A SENSE, BE MULTIPLIED BY THE TWO FACTORS    SCLOUD   213
CLJ       CFLOSF(1,THR) AND CFLOSF(1,THI).  WE SHALL NOT USE THE FACTORS SCLOUD  214
CLJ       HERE FOR CONSISTENCY WITH SUCH NONUSAGE ELSEWHERE IN THE CODE. SCLOUD  215
CLJ       (THE CONFUSION ARISES FROM THE AMBIGUITY IN THE LITERATURE AS SCLOUD   216
CLJ       TO WHAT IS MEANT BY A CLOUD COVER OF ZERO TENTHS, WHEN CFLOSF SCLOUD   217
CLJ       IS LESS THAN UNITY FOR SUFFICIENTLY LARGE ZENITH ANGLES.  A   SCLOUD   218
CLJ       COMPLEMENTARY-TYPE AMBIGUITY EXITS FOR A CLOUD COVER OF TEN   SCLOUD   219
CLJ       TENTHS, WHEN CFLOSF IS GREATER THAN ZERO.)                    SCLOUD   220
CLJ       THE PROBABILITY OF SEEING THE SOURCE-LIT GROUND EITHER WITH   SCLOUD   221
CLJ       OR WITHOUT CLOUDS BEING PRESENT IS SLG...                     SCLOUD   222
      SLG = SLGCLD + SLGCLR                                             SCLOUD   223
      IF( SLG.GT.1.0 )  SLG = 1.0                                       SCLOUD   224
CLJ       TO REFERENCE THE TRANSFER COEFFICIENT TO 12-KM ALTITUDE, WE   SCLOUD   225
CLJ       NEED SDISTO.  IN DOING THIS WE USE THE ORIGINAL SOURCE        SCLOUD   226
CLJ       POSITION, WITHOUT ANY RESETTING IF THE SOURCE IS ARTIFICIAL,  SCLOUD   227
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CLJ       EVEN THOUGH ITS ALTITUDE MAY BE LESS THAN ITS RADIUS.           SCLOUD   228
      TPALT = 12.                                                         SCLOUD   229
      CALL SGEOM(UL,VL,WL,TPALT,XD,YD,ZD,XS,YS,ZS,                        SCLOUD   230
     $          RDIST,SDISTO,THETI,THETE,PHIE)                            SCLOUD   231
      T12 = TAIR(ALAM,THI,ZKM)                                            SCLOUD   232
      IF( HSORCE(1).LT.12. )  T12 = T12/TAIR(ALAM,THI,HSORCE(1))          SCLOUD   233
      TRANS(II) = SFR*COS(THI*DTR)*T12*T2TP*(SDISTO/SDIST)**2             SCLOUD   234
      HSORCE(1) = HSAVE2                                                  SCLOUD   235
    4 CONTINUE                                                            SCLOUD   236
CLJ       BEFORE DUPLICATING THE WT ARRAY AND BEFORE SORTING THE TRANS    SCLOUD   237
CLJ       AND EMISS ARRAYS, AUGMENT THE TRANS ARRAY WITH THE MEMBER       SCLOUD   238
CLJ       TRANS(II+1) = 0.0, THE EMISSION ARRAY WITH THE MEMBER           SCLOUD   239
CLJ       EMISS(II+1) = 0.0, AND THE WT ARRAY WITH THE MEMBER             SCLOUD   240
CLJ       WT(II+1) = 0.0.  DOING THIS ALLOWS SUBROUTINE LINEAR TO         SCLOUD   241
CLJ       INTERPOLATE WITHIN ITS GIVEN ARRAY IF THE WEIGHT OF THE         SCLOUD   242
CLJ       NORMALLY SMALLEST MEMBER EXCEEDS THE SMALLEST FRACTILE (NOW      SCLOUD   243
CLJ       0.10) FOR WHICH AN INTEGRAL-DISTRIBUTION VALUE IS REQUESTED.    SCLOUD   244
      IISAVE = II                                                         SCLOUD   245
      II = II + 1                                                         SCLOUD   246
      TRANS(II) = 0.0                                                     SCLOUD   247
      EMISS(II) = 0.0                                                     SCLOUD   248
      WT(II) = 0.0                                                        SCLOUD   249
      DO 5 I = 1,II                                                       SCLOUD   250
    5 WT1(I) = WT(I)                                                      SCLOUD   251
CLJ       NOW RESET WT(IISAVE) TO ACCOUNT FOR A TWO-LEG CFLOS.            SCLOUD   252
      IF( ITFLAG .NE. 0 )  WT(IISAVE) = SLG                               SCLOUD   253
C                                                                         SCLOUD   254
CLJ       SORT THE ARRAYS FOR TRANSFER COEFFICIENT AND EMISSION, TRANS    SCLOUD   255
CLJ       AND EMISS, FROM LOW TO HIGH.                                    SCLOUD   256
C                                                                         SCLOUD   257
      IF( ITFLAG.NE.0 )  CALL SORTLJ(TRANS,WT,WT,II,0)                    SCLOUD   258
      CALL SORTLJ(EMISS,WT1,WT1,II,0)                                     SCLOUD   259
C        ACCUMULATE THE WEIGHTING FUNCTION AND NORMALIZE                  SCLOUD   260
      DO 10 I = 2,II                                                      SCLOUD   261
      WT1(I) = WT1(I-1) + WT1(I)                                          SCLOUD   262
   10 WT(I) = WT(I-1) + WT(I)                                             SCLOUD   263
      DO 15 I = 1,II                                                      SCLOUD   264
      WT1(I) = WT1(I) / WT1(II)                                           SCLOUD   265
   15 WT(I) = WT(I) / WT(II)                                              SCLOUD   266
C                                                                         SCLOUD   267
CLJ       INTERPOLATE TO THE FRACTILES P1,P2,P3,P4 SET IN THE DRIVER.     SCLOUD   268
      IF( ISUN.EQ.1 )  GO TO 22                                           SCLOUD   269
      CALL LINEAR(P1,E1,WT1,EMISS,II)                                     SCLOUD   270
      CALL LINEAR(P2,E2,WT1,EMISS,II)                                     SCLOUD   271
      CALL LINEAR(P3,E3,WT1,EMISS,II)                                     SCLOUD   272
      CALL LINEAR(P4,E4,WT1,EMISS,II)                                     SCLOUD   273
      CALL LINEAR(P1,T1,WT,TRANS,II)                                      SCLOUD   274
      CALL LINEAR(P2,T2,WT,TRANS,II)                                      SCLOUD   275
      CALL LINEAR(P3,T3,WT,TRANS,II)                                      SCLOUD   276
      CALL LINEAR(P4,T4,WT,TRANS,II)                                      SCLOUD   277
      IF( ISUN.EQ.0 )  GO TO 24                                           SCLOUD   278
   22 CONTINUE                                                            SCLOUD   279
      CALL LINEAR(P1,E1,WT1,EMISS,II)                                     SCLOUD   280
      CALL LINEAR(P2,E2,WT1,EMISS,II)                                     SCLOUD   281
      CALL LINEAR(P3,E3,WT1,EMISS,II)                                     SCLOUD   282
      CALL LINEAR(P4,E4,WT1,EMISS,II)                                     SCLOUD   283
      IF( ITFLAG.EQ.0 )  GO TO 24                                         SCLOUD   284
```

```
      CALL LINEAR(P1,S1,WT,TRANS,II)                                     SCLOUD  285
      CALL LINEAR(P2,S2,WT,TRANS,II)                                     SCLOUD  286
      CALL LINEAR(P3,S3,WT,TRANS,II)                                     SCLOUD  287
      CALL LINEAR(P4,S4,WT,TRANS,II)                                     SCLOUD  288
   24 CONTINUE                                                           SCLOUD  289
      HSORCE(1) = HSAVE                                                  SCLOUD  290
      IF( ISUN.EQ.1 )  GO TO 30                                          SCLOUD  291
CLJ       FINALLY, WE RETURN TO THE USER THROUGH PTE COMMON THE          SCLOUD  292
CLJ       PROBABILITY (PCFLOS) OF SEEING THE ARTIFICIAL SOURCE           SCLOUD  293
CLJ       (PROVIDED IT IS WITHIN THE FIELD-OF-VIEW), EITHER WITH CLOUDS  SCLOUD  294
CLJ       BEING PRESENT (AND WITH ACCOUNT OF OUR POSTULATED ALTITUDE-    SCLOUD  295
CLJ       DEPENDENT CFLOS FUNCTION) OR WITHOUT CLOUDS BEING PRESENT.     SCLOUD  296
CLJ                                                                      SCLOUD  297
      PCFLOS = 0.0                                                       SCLOUD  298
CLJ                                                                      SCLOUD  299
CLJ       THE CHARACTERISTIC HALF-ANGLE OF THE FIELD-OF-VIEW IS          SCLOUD  300
CLJ       TAKEN TO BE CHIFOV...                                          SCLOUD  301
CLJ                                                                      SCLOUD  302
      CHIFOV = SQRT( FOV/PI ) / HD                                       SCLOUD  303
CLJ                                                                      SCLOUD  304
CLJ       GET THE DIRECTION COSINES OF A VECTOR FROM THE DETECTOR        SCLOUD  305
CLJ       TO THE SOURCE.                                                 SCLOUD  306
      RSD = SQRT( (XS-XD)**2 + (YS-YD)**2 + (ZS-ZD)**2 )                 SCLOUD  307
      US = (XS-XD)/RSD                                                   SCLOUD  308
      VS = (YS-YD)/RSD                                                   SCLOUD  309
      WS = (ZS-ZD)/RSD                                                   SCLOUD  310
CLJ       THE ANGLE BETWEEN THE INPUT LOS AND THE DETECTOR-TO-SOURCE     SCLOUD  311
CLJ       VECTOR IS CHISL...                                             SCLOUD  312
      CHISL = ACOS( US*UL + VS*VL + WS*WL )                              SCLOUD  313
      IF( CHISL.GT.CHIFOV )  GO TO 30                                    SCLOUD  314
CLJ       SINCE THE SOURCE IS WITHIN THE FIELD-OF-VIEW, COMPUTE PCFLOS.  SCLOUD  315
      PCFLOS = CCOVER(2,KMODEL) * CFLOSH( 4,THR,F)                       SCLOUD  316
     $      + CCOVER(3,KMODEL) * CFLOSH( 6,THR,F)                        SCLOUD  317
     $      + CCOVER(4,KMODEL) * CFLOSH( 9,THR,F)                        SCLOUD  318
     $      + CCOVER(5,KMODEL) * CFLOSH(11,THR,F) + CCOVER(1,KMODEL)     SCLOUD  319
   30 CONTINUE                                                           SCLOUD  320
      RETURN                                                             SCLOUD  321
      END                                                                SCLOUD  322
```

```
      SUBROUTINE SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,                SGEOM     2
     X RDIST,SDIST,THETI,THETE,PHIE )                                    SGEOM     3
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                             PARAMS    2
C         ANGLES IN DEGREES AND DISTANCES IN KILOMETERS                  SGEOM     5
C                                                                        SGEOM     6
C         INPUTS                                                         SGEOM     7
C         UL,VL,WL   ARE LOS DIRECTION COSINES                           SGEOM     8
C         CLDTOP   CLOUD TOP ALTITUDE                                    SGEOM     9
C         XD,YD,ZD - XS,YS,ZS  DETECTOR AND SOURCE LOCATION..EARTH CENT  SGEOM    10
C                                                                        SGEOM    11
C         THIS IS CODE FOR THE INCIDENT AND EXIT LOOK ANGLES             SGEOM    12
C         AND THE AZIMUTHAL ANGLE FOR SOURCE ABOVE THE CLOUD             SGEOM    13
C         THE VECTOR RI IS TO THE CLOUD TOP FROM THE EARTH CENTER        SGEOM    14
C         S IS THE DISTANCE FROM THE DETECTOR TO THE CLOUD TOP           SGEOM    15
C                                                                        SGEOM    16
C         THETI IS THE INCIDENT LOOK ANGLE                               SGEOM    17
C         THETE IS THE EXIT LOOK ANGLE                                   SGEOM    18
C         PHIE IS THE AZIMUTHAL ANGLE I.E. THE ANGLE BETWEEN THE         SGEOM    19
C         RS,RI PLANE AND THE RD,RI PLANE                                SGEOM    20
C         SDIST IS DISTANCE FROM SOURCE TO INTERSECTION OF CLOUD TOP AND SGEOM    21
C         LINE-OF-SIGHT  (KILOMETERS)                                    SGEOM    22
C         RDIST IS HORIZONTAL COMPONENT OF SDIST                         SGEOM    23
C                                                                        SGEOM    24
CCC                                                                      SGEOM    25
CLJ   SUBROUTINE SGEOM COMPUTES THE GEOMETRICAL RELATIONS BETWEEN        SGEOM    26
CLJ   A SOURCE, STATISTICAL CLOUD, AND DETECTOR.                         SGEOM    27
CCC                                                                      SGEOM    28
CLJ   INPUT PARAMETERS                                                   SGEOM    29
CLJ     ARGUMENT LIST                                                    SGEOM    30
CLJ         UL,VL,WL = DIRECTION COSINES IN THE GEOCENTRIC CARTESIAN     SGEOM    31
CLJ                    COORDINATE SYSTEM OF THE LINE-OF-SIGHT (LOS)      SGEOM    32
CLJ                    VECTOR FROM THE DETECTOR                          SGEOM    33
CLJ        CLDTOP    = ALTITUDE OF THE (STATISTICAL) CLOUD TOP INTER-    SGEOM    34
CLJ                    SECTED BY THE LOS FROM THE DETECTOR,  KM          SGEOM    35
CLJ         XD,YD,ZD = GEOCENTRIC CARTESIAN COORDINATES OF THE           SGEOM    36
CLJ                    DETECTOR,  KM                                     SGEOM    37
CLJ         XS,YS,ZS = GEOCENTRIC CARTESIAN COORDINATES OF THE           SGEOM    38
CLJ                    SOURCE,  KM                                       SGEOM    39
CLJ     PARAMS COMMON                                                    SGEOM    40
CLJ              DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS, PI/180 SGEOM    41
CLJ              RTD = CONVERSION FACTOR FROM RADIANS TO DEGREES, 180/PI SGEOM    42
CLJ               RE = EARTH RADIUS,  KM                                 SGEOM    43
CLJ   OUTPUT PARAMETERS                                                  SGEOM    44
CLJ     ARGUMENT LIST                                                    SGEOM    45
CLJ            SDIST = DISTANCE FROM THE SOURCE TO THE INTERSECTION OF   SGEOM    46
CLJ                    THE DETECTOR LOS VECTOR WITH THE HORIZONTAL       SGEOM    47
CLJ                    SURFACE WHOSE ALTITUDE IS INPUTTED TO THIS        SGEOM    48
CLJ                    ROUTINE AS CLDTOP, KM                             SGEOM    49
CLJ                    (INTERSECTION POINT DENOTED BY VECTOR RI IN THE   SGEOM    50
CLJ                    GEOCENTRIC CARTESIAN COORDINATE SYSTEM)           SGEOM    51
CLJ            RDIST = COMPONENT OF SDIST NORMAL TO THE VECTOR RI,  KM   SGEOM    52
CLJ            THETI = ZENITH ANGLE OF SOURCE AT POINT RI,  DEGREES      SGEOM    53
CLJ            THETE = ZENITH ANGLE OF DETECTOR AT POINT RI,  DEGREES    SGEOM    54
CLJ             PHIE = AZIMUTHAL ANGLE THROUGH WHICH A PHOTON IS         SGEOM    55
CLJ                    DEFLECTED AT THE POINT RI WHILE GOING FROM THE    SGEOM    56
CLJ                    SOURCE TO THE DETECTOR,  DEGREES                  SGEOM    57
CCC                                                                      SGEOM    58
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      RD = XD**2 + YD**2 + ZD**2                                        SGEOM  59
      S = UL*XD + VL*YD + WL*ZD                                         SGEOM  60
      S = - S - SQRT(S**2 - RD + (RE+CLDTOP)**2)                        SGEOM  61
      RD = SQRT(RD)                                                     SGEOM  62
      XI = XD + S*UL                                                    SGEOM  63
      YI = YD + S*VL                                                    SGEOM  64
      ZI = ZD + S*WL                                                    SGEOM  65
C                                                                       SGEOM  66
C        READ THE VARIABLE NAMES AS                                     SGEOM  67
C        R DMIDMI  MEANING (RD MINUS RI) DOT (RD MINUS RI) ETC.         SGEOM  68
      RDMIDMI = (XD-XI)*(XD-XI) + (YD-YI)*(YD-YI) + (ZD-ZI)*(ZD-ZI)     SGEOM  69
      RSMISMI = (XS-XI)*(XS-XI) + (YS-YI)*(YS-YI) + (ZS-ZI)*(ZS-ZI)     SGEOM  70
      SDIST = SQRT( RSMISMI )                                           SGEOM  71
      RISMI  =      XI * (XS-XI) +   YI *  (YS-YI) +    ZI * (ZS-ZI)    SGEOM  72
       R DDOTI = XD*XI + YD*YI + ZD*ZI                                  SGEOM  73
       R DDOTS = XD*XS + YD*YS + ZD*ZS                                  SGEOM  74
       R SDOTI = XI*XS + YI*YS + ZI*ZS                                  SGEOM  75
       R IDOTI = XI*XI + YI*YI + ZI*ZI                                  SGEOM  76
       R DDOTD = XD*XD + YD*YD + ZD*ZD                                  SGEOM  77
       R SDOTS = XS*XS + YS*YS + ZS*ZS                                  SGEOM  78
      RS = SQRT( XS**2 + YS**2 + ZS**2 )                                SGEOM  79
      US = XS / RS                                                      SGEOM  80
      VS = YS / RS                                                      SGEOM  81
      WS = ZS / RS                                                      SGEOM  82
      RI = SQRT( RIDOTI )                                               SGEOM  83
      D1 = XI*US + YI*VS + ZI*WS                                        SGEOM  84
      D2 = XI*UL + YI*VL + ZI*WL                                        SGEOM  85
      D3 = UL*US + VL*VS + WL*WS                                        SGEOM  86
      THETE = ACOS( -D2/RI )                                            SGEOM  87
      THETI = ACOS( RISMI/( RI*SDIST ) )                                SGEOM  88
C                                                                       SGEOM  89
C        CHECK FOR COLINEARITY,  IF SO, PHIE = 0                        SGEOM  90
C                                                                       SGEOM  91
      PHIE = 1.0E-05                                                    SGEOM  92
      IF(ABS (RSDOTS*RIDOTI / RSDOTI**2)  .GT. .999999) GO TO 10        SGEOM  93
      IF(ABS (RDDOTD*RIDOTI / RDDOTI**2)  .GT. .999999) GO TO 10        SGEOM  94
      PHIE = 0.0                                                        SGEOM  95
      IF( (THETE.EQ.0.0) .OR. (THETI.EQ.0.0) )  GO TO 10                SGEOM  96
      PHIE = ACOS( (RI*COS(THETE)*D1 + RIDOTI*D3) /                     SGEOM  97
     $      (RIDOTI*SIN(THETE)*SIN(THETI)) )                            SGEOM  98
   10 CONTINUE                                                          SGEOM  99
      THETE = THETE * RTD                                               SGEOM 100
      THETI = THETI * RTD                                               SGEOM 101
      PHIE = PHIE * RTD                                                 SGEOM 102
      RDIST = SDIST * SIN(THETI*DTR)                                    SGEOM 103
      RETURN                                                            SGEOM 104
      END                                                               SGEOM 105
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      SUBROUTINE SORTLJ(A,B,C,N,LOHI)                                   SORTLJ   2
CCC                                                                     SORTLJ   3
C           GIVEN THE A ARRAY OF LENGTH N, THIS ROUTINE SORTS THE       SORTLJ   4
C           ARRAY FROM LOW TO HIGH IF LOHI.LE.0 AND FROM HIGH TO LOW    SORTLJ   5
C           IF LOHI.GT.0  .                                             SORTLJ   6
C           THE B AND C ARRAYS ARE SIMPLY CARRIED ALONG                 SORTLJ   7
CCC                                                                     SORTLJ   8
      DIMENSION  A(2), B(2), C(2)                                       SORTLJ   9
      M = N                                                             SORTLJ  10
   20 M = M/2                                                           SORTLJ  11
      IF( M.EQ.0 ) GO TO 40                                             SORTLJ  12
      K = N-M                                                           SORTLJ  13
      J = 1                                                             SORTLJ  14
   41 I = J                                                             SORTLJ  15
   49 L = I+M                                                           SORTLJ  16
      IF( LOHI )  50,50,52                                              SORTLJ  17
C                                                                       SORTLJ  18
C * * * SORT LOW TO HIGH.                                               SORTLJ  19
   50 IF( A(L).GE.A(I) ) GO TO 60                                       SORTLJ  20
      GO TO 55                                                          SORTLJ  21
C                                                                       SORTLJ  22
C * * * SORT HIGH TO LOW.                                               SORTLJ  23
   52 IF( A(L).LE.A(I) ) GO TO 60                                       SORTLJ  24
   55 X = A(I)                                                          SORTLJ  25
      A(I) = A(L)                                                       SORTLJ  26
      A(L) = X                                                          SORTLJ  27
      Y = B(I)                                                          SORTLJ  28
      Z = C(I)                                                          SORTLJ  29
      B(I) = B(L)                                                       SORTLJ  30
      C(I) = C(L)                                                       SORTLJ  31
      B(L) = Y                                                          SORTLJ  32
      C(L) = Z                                                          SORTLJ  33
      I = I-M                                                           SORTLJ  34
      IF( I.GE.1 ) GO TO 49                                             SORTLJ  35
   60 J = J+1                                                           SORTLJ  36
      IF( J-K ) 41,41,20                                                SORTLJ  37
   40 RETURN                                                            SORTLJ  38
      END                                                               SORTLJ  39
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      FUNCTION TAIR(ALAM,THETA,ALT)                                      TAIR   2
      DIMENSION T(10,6,4)                                                TAIR   3
      DIMENSION TLAM(10),TALT(6),STHET(4)                                TAIR   4
      DATA TLAM / 2.0,2.5,2.55,2.65,2.75,2.85,3.2,3.5,4.0,5.0 /          TAIR   5
      DATA TALT / 1.,2.,4.,6.,8.,12.  /                                  TAIR   6
      DATA STHET / 1.,2.,3.864,11.4737 /                                 TAIR   7
C                                                                        TAIR   8
C                                                                        TAIR   9
C        THE FIRST INDEX IS ON WAVELENGTH                                TAIR  10
C        THE SECOND INDEX IS ON ALTITUDE                                 TAIR  11
C        THE THIRD INDEX IS ON ANGLE                                     TAIR  12
C                                                                        TAIR  13
CLJ       THE INTERPOLATION (AND EXTRAPOLATION FOR THETA .GT. 85         TAIR  14
CLJ       DEGREES AND ALT .LT. 1 KM) IS LINEAR IN (LN(T),SEC(THETA))-,   TAIR  15
CLJ       (T,ALAM)-, AND (LN(T),ALT)-SPACE.  HOWEVER, FOR THETA .GT.     TAIR  16
CLJ       85 DEGREES, SEC(THETA) IS REDEFINED BY A PARABOLIC             TAIR  17
CLJ       APPROXIMATION TO THE CHAPMAN FUNCTION.                         TAIR  18
C                                                                        TAIR  19
C                                                                        TAIR  20
C        THE TRANSMISSION IS FROM LOWTRAN III FOR 1962 STD ATMOSPHERE    TAIR  21
C                                                                        TAIR  22
C        THE FOLLOWING TABLE CONTAINS THE TRANSMISSION                   TAIR  23
C        FROM 1 TO 12KM, 2 TO 12KM ETC., NOT FROM ONE ALTITUDE TO        TAIR  24
C        THE TOP OF THE ATMOSPHERE                                       TAIR  25
C                                                                        TAIR  26
CCC                                                                      TAIR  27
CLJ   FUNCTION  TAIR COMPUTES THE TRANSMITTANCE FOR RADIATION OF         TAIR  28
CLJ   WAVELENGTH ALAM FROM ALTITUDE ALT TO 12 KM ALONG A PATH AT         TAIR  29
CLJ   ZENITH ANGLE THETA.                                                TAIR  30
CCC                                                                      TAIR  31
CLJ   INPUT PARAMETERS                                                   TAIR  32
CLJ      ARGUMENT LIST                                                   TAIR  33
CLJ            ALAM = WAVELENGTH,  MICRONS                               TAIR  34
CLJ           THETA = ZENITH ANGLE,  DEGREES                             TAIR  35
CLJ             ALT = ALTITUDE,  KM                                      TAIR  36
CLJ   OUTPUT PARAMETER                                                   TAIR  37
CLJ      FUNCTION                                                        TAIR  38
CLJ            TAIR = TRANSMITTANCE FOR RADIATION OF WAVELENGTH ALAM     TAIR  39
CLJ                   FROM ALTITUDE ALT TO 12 KM ALONG PATH AT           TAIR  40
CLJ                   ZENITH ANGLE THETA                                 TAIR  41
CLJ   DEFINITION OF DATA                                                 TAIR  42
CLJ         T(I,J,K) = TRANSMITTANCE FOR RADIATION OF WAVELENGTH         TAIR  43
CLJ                    TLAM(I) ALONG PATH AT ZENITH ANGLE THETA(K)=      TAIR  44
CLJ                    ACOS( 1./STHET(K) ) FROM ALTITUDE TALT(J) TO      TAIR  45
CLJ                    12 KM          I=1,10  J=1,6  K=1,4               TAIR  46
CLJ         THETA(K) = 0,60,75,85  DEGREES         K=1,4                 TAIR  47
CCC                                                                      TAIR  48
      DATA (T(I,1,1) ,I=1,60) /                                          TAIR  49
     X .4093,.2150,.0009,.0009,.0001,.0107,.2042,.8398,.8973,.4081,      TAIR  50
     X .4690,.3247,.0010,.0010,.0001,.0370,.3038,.8880,.9239,.5183,      TAIR  51
     X .5800,.5681,.0232,.0198,.0001,.1893,.5217,.9474,.9568,.7284,      TAIR  52
     X .6834,.7758,.1834,.1723,.0043,.4413,.7199,.9744,.9762,.8636,      TAIR  53
     X .7788,.9064,.5081,.4649,.0440,.7240,.8549,.9925,.9889,.9479,      TAIR  54
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /   TAIR  55
      DATA (T(I,1,2) ,I=1,60) /                                          TAIR  56
     X .2753,.1063,.0008,.0008,.0001,.0007,.0978,.7645,.8070,.2728,      TAIR  57
     X .3313,.1952,.0009,.0009,.0001,.0073,.1753,.8257,.8544,.3863,      TAIR  58
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     X .4151,.4358,.0033,.0022,.0001,.0898,.3853,.9150,.9163,.6227,     TAIR
     X .5648,.5823,.0848,.0765,.0003,.3065,.6127,.9625,.9531,.8081,     TAIR
     X .6817,.8623,.3792,.3652,.0094,.6060,.7874,.9861,.9733,.9210,     TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /  TAIR
      DATA (T(I,1,3) ,I=1,60) /                                         TAIR
     X .1151,.0363,.0008,.0008,.0001,.0006,.0338,.6544,.6620,.1559,     TAIR
     X .2069,.0960,.0008,.0008,.0001,.0007,.0822,.7461,.7401,.2579,     TAIR
     X .3179,.3065,.0009,.0009,.0001,.0287,.2587,.8683,.8460,.5006,     TAIR
     X .4347,.5742,.0259,.0224,.0001,.1855,.4908,.9388,.9125,.7328,     TAIR
     X .5725,.8094,.2502,.2368,.0011,.4807,.7131,.9755,.9549,.8818,     TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /  TAIR
      DATA (T(I,1,4) ,I=1,60) /                                         TAIR
     X .0330,.0014,.0006,.0006,.0001,.0004,.0017,.3949,.3140,.0344,     TAIR
     X .0586,.0125,.0007,.0007,.0001,.0004,.0096,.5349,.4282,.0874,     TAIR
     X .1291,.1208,.0008,.0008,.0001,.0009,.0879,.7463,.6242,.2915,     TAIR
     X .2294,.3680,.0010,.0009,.0001,.0476,.2729,.8674,.7712,.5590,     TAIR
     X .3658,.6700,.0828,.0745,.0001,.2725,.5372,.9405,.8768,.7991,     TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /  TAIR
CCC                                                                     TAIR
      BETA = AMIN1( THETA,(180.-THETA) )                                TAIR
      STHETA = 1.0 / COS( BETA/57.2958 )                                TAIR
CCC                                                                     TAIR
CLJ       FOR BETA .GT. 85 DEGREES, REDEFINE SEC(BETA) BY A SIMPLE     TAIR
CLJ       PARABOLIC APPROXIMATION TO THE CHAPMAN FUNCTION.             TAIR
CCC                                                                     TAIR
      IF( BETA.GT.85. )  STHETA = 1.0 / COS( 85./57.2958 )              TAIR
     $                            + 1.1*(BETA-85.)**2                   TAIR
CCC                                                                     TAIR
CLJ       FIND THE INDEX I FOR THE FIRST TABULAR WAVELENGTH LESS THAN  TAIR
CLJ       OR EQUAL TO ALAM (USE I=9 IF ALAM=5.0).                      TAIR
      DO 10 II = 2,10                                                   TAIR
      I = II   - 1                                                      TAIR
      IF(ALAM .LT. TLAM(II))GO TO 15                                    TAIR
   10 CONTINUE                                                          TAIR
      I = 9                                                             TAIR
   15 CONTINUE                                                          TAIR
CLJ       FIND THE INDEX J FOR THE FIRST TABULAR ALTITUDE LESS THAN    TAIR
CLJ       OR EQUAL TO ALT (BUT ONLY LESS IF ALT=12.0.  ALSO, USE J=1 IF TAIR
CLJ       ALT .LE. 1.0).                                               TAIR
      DO 20 JJ = 2,6                                                    TAIR
      J = JJ - 1                                                        TAIR
      IF(ALT .LT. TALT(JJ) ) GO TO 25                                   TAIR
   20 CONTINUE                                                          TAIR
      J = 5                                                             TAIR
   25 CONTINUE                                                          TAIR
CLJ       FIND THE INDEX K FOR THE FIRST TABULAR SEC(THETA) LESS THAN  TAIR
CLJ       OR EQUAL TO STHETA (BUT USE K=3 IF 85.LE.THETA.LE.90 DEGREES) TAIR
      DO 30 KK = 2,4                                                    TAIR
      K = KK - 1                                                        TAIR
      IF(STHETA .LT. STHET(KK)) GO TO 35                                TAIR
   30 CONTINUE                                                          TAIR
      K = 3                                                             TAIR
   35 CONTINUE                                                          TAIR
      H = ALT                                                           TAIR
CLJ       FIND THE FRACTIONAL DISTANCE, TLAMX, ALAM LIES BETWEEN       TAIR
CLJ       TLAM(I) AND TLAM(I+1).                                       TAIR
      TLAMX = (ALAM - TLAM(I)) / (TLAM(I+1) - TLAM(I))                  TAIR
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C                                                                       TAIR 116
      TL1 = T(I,J  ,K  ) + (T(I+1,J  ,K  ) - T(I,J  ,K  )) * TLAMX      TAIR 117
      TL2 = T(I,J  ,K+1) + (T(I+1,J  ,K+1) - T(I,J  ,K+1)) * TLAMX      TAIR 118
      TL3 = T(I,J+1,K  ) + (T(I+1,J+1,K  ) - T(I,J+1,K  )) * TLAMX      TAIR 119
      TL4 = T(I,J+1,K+1) + (T(I+1,J+1,K+1) - T(I,J+1,K+1)) * TLAMX      TAIR 120
      B1 = (TL2/TL1)**(1. / (STHET(K+1) - STHET(K)))                    TAIR 121
      B2 = (TL4/TL3)**(1. / (STHET(K+1) - STHET(K)))                    TAIR 122
      A1 = TL1 / (B1**STHET(K))                                         TAIR 123
      A2 = TL3 / (B2**STHET(K))                                         TAIR 124
      TLT1 = A1*B1**STHETA                                              TAIR 125
      TLT2 = A2*B2**STHETA                                              TAIR 126
      B = ALOG(TLT2 / TLT1) / (TALT(J+1) - TALT(J))                     TAIR 127
      A = TLT1 / EXP(B*TALT(J))                                         TAIR 128
      TAIR = A * EXP(B * H)                                             TAIR 129
      RETURN                                                            TAIR 130
      END                                                               TAIR 131
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```
      FUNCTION TRANSF(ALAM,LL,MM,HH)                                    TRANS      2
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON/SORCE/  NSORCE,MSORCE(1),RSORCE(1),THETAS(1),PHIS(1)       SORCE      2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XNUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      COMMON/DIFFUS/DALFA(14),DBETA(14),DKAPPA(14)                      DIFCOM     2
      COMMON/FLAGS/  ITFLAG                                             FLAGS      2
      COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL                         SANDD      2
      DIMENSION THKN(3),DALFAN(3),DBETAN(3),DKAPPAN(3)                  TRANS      9
      DIMENSION LINDEX(3),A(4)                                          TRANS     10
      INTEGER HH                                                        TRANS     11
CCC                                                                     TRANS     12
CLJ   FUNCTION TRANSF COMPUTES A QUANTITY DEFINED IN THE NATURAL CLOUD  TRANS     13
CLJ   MODEL AS THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT (1/SR)   TRANS     14
CLJ   OR SIMPLY THE TRANSFER COEFFICIENT AT THE INTERSECTION OF THE     TRANS     15
CLJ   DETECTOR LOS VECTOR WITH 12-KM ALTITUDE (KNOWN AS THE TRANSFER    TRANS     16
CLJ   POINT).  THE TRANSFER COEFFICIENT IS ACTUALLY THE RATIO OF A      TRANS     17
CLJ   RADIANCE AND AN IRRADIANCE.  THE RADIANCE IS THAT DIRECTED ANTI-  TRANS     18
CLJ   PARALLEL TO THE DETECTOR LOS VECTOR AND THE IRRADIANCE IS THE     TRANS     19
CLJ   (UNATTENUATED) SOURCE IRRADIANCE AT THE TRANSFER POINT.  FOR A    TRANS     20
CLJ   SOURCE ABOVE 12-KM ALTITUDE AND FAR FROM THE TRANSFER POINT (AS   TRANS     21
CLJ   FOR THE SUN), THE TRANSFER COEFFICIENT BECOMES ESSENTIALLY THE    TRANS     22
CLJ   BIDIRECTIONAL REFLECTANCE OF THE CLOUD TOP TIMES THE COSINE OF    TRANS     23
CLJ   THE ZENITH ANGLE OF THE INCIDENT RAY.  FOR A SOURCE BELOW OR      TRANS     24
CLJ   WITHIN THE CLOUDS, THE TRANSFER COEFFICIENT DEPENDS ON THE        TRANS     25
CLJ   DETAILS OF THE DIFFUSION SOLUTION TO THE TRANSPORT OF RADIATION   TRANS     26
CLJ   THROUGH THE CLOUDS.                                               TRANS     27
CCC                                                                     TRANS     28
CLJ   INPUT PARAMETERS                                                  TRANS     29
CLJ      ARGUMENT LIST                                                  TRANS     30
CLJ            ALAM = WAVELENGTH,  MICRONS                              TRANS     31
CLJ              LL = INDEX (1,7) OF ONE OF SEVEN LOW-ALTITUDE CLOUDS   TRANS     32
CLJ                 = KCLOUD                                            TRANS     33
CLJ              MM = INDEX (1,3) OF ONE OF THREE MID-ALTITUDE CLOUDS   TRANS     34
CLJ                 = KCLOUD-7                                          TRANS     35
CLJ              HH = INDEX (1,4) OF ONE OF FOUR HIGH-ALTITUDE CLOUDS   TRANS     36
CLJ                 = KCLOUD-10                                         TRANS     37
CLJ                   (KCLOUD = CLOUD-TYPE INDEX)                       TRANS     38
CLJ      FLAGS COMMON                                                   TRANS     39
CLJ          ITFLAG = 0  IF SUN IS BELOW THE HORIZON                    TRANS     40
CLJ                 = 1  IF SUN IS ABOVE THE HORIZON                    TRANS     41
CLJ      CDDATA COMMON                                                  TRANS     42
CLJ         CLDBASE(K) = ALTITUDE ABOVE EARTH SURFACE OF BASE OF        TRANS     43
CLJ                      CLOUD-TYPE K,  KM         K=1,14               TRANS     44
CLJ          CLDTHK(K) = THICKNESS OF CLOUD-TYPE K,  KM     K=1,14      TRANS     45
CLJ      DIFFUS COMMON                                                  TRANS     46
CLJ           DALFA(K) = 0.25 TIMES THE RATIO OF SCATTERING CROSS-      TRANS     47
CLJ                      SECTION TO TOTAL CROSS-SECTION FOR PHOTONS OF  TRANS     48
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K, DIMENSIONLESS TRANS     49
CLJ           DBETA(K) = 0.50 TIMES THE DIFFUSION COEFFICIENT FOR       TRANS     50
CLJ                      PHOTONS OF WAVELENGTH ALAM IN CLOUD-TYPE K,  KM TRANS    51
CLJ          DKAPPA(K) = INVERSE DIFFUSION LENGTH FOR PHOTONS OF        TRANS     52
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K,  1/KM         TRANS     53
CCC                                                                     TRANS     54
CLJ                 FOR ABOVE VARIABLES   K=1,14                        TRANS     55
CLJ      THE ABOVE DEFINITIONS FOR THE DIFFUSION PARAMETERS APPLY TO A  TRANS     56
CLJ      WEAKLY ABSORBING MEDIUM.  FOR A STRONGLY ABSORBING MEDIUM,     TRANS     57
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CLJ       MODIFIED DIFFUSION PARAMETERS ARE REQUIRED.  WE ALSO COMPUTE   TRANS
CLJ       THE LATTER TYPE AND USE THEM AFTER 9/30/78.                    TRANS
CCC                                                                      TRANS
CLJ     SANDD COMMON                                                     TRANS
CLJ          UL,VL,WL = DETECTOR LOS DIRECTION COSINES                   TRANS
CLJ          XD,YD,ZD = DETECTOR GEOCENTRIC CARTESIAN COORDINATES,  KM   TRANS
CLJ          XS,YS,ZS = SOURCE GEOCENTRIC CARTESIAN COORDINATES,  KM     TRANS
CLJ     SORCE COMMON                                                     TRANS
CLJ         NSORCE      = NUMBER OF SOURCES BEING CONSIDERED             TRANS
CLJ         HSORCE(N) = ALTITUDE OF SOURCE-N                             TRANS
CLJ        RSORCE(N) = RADIUS OF SOURCE-N,  KM                           TRANS
CLJ   OUTPUT PARAMETER                                                   TRANS
CLJ     FUNCTION                                                         TRANS
CLJ         TRANSF = THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT     TRANS
CLJ                  AT THE TRANSFER POINT,  1/SR                        TRANS
CLJ                  (SEE ABOVE FOR FULLER DESCRIPTION)                  TRANS
CCC                                                                      TRANS
      SINH(ARG) = (EXP(ARG) - EXP(-ARG)) / 2.                            TRANS
      COSH(ARG) = (EXP(ARG) + EXP(-ARG)) / 2.                            TRANS
COMMENTS....                                                             TRANS
CLJ       THERE ARE 7 LOW-LAYER CLOUDS FOR WHICH THE INDEX IS LL=1,7     TRANS
CLJ       THERE ARE 3 MID-LAYER CLOUDS FOR WHICH THE INDEX IS MM=1,3     TRANS
CLJ       THERE ARE 4  HI-LAYER CLOUDS FOR WHICH THE INDEX IS HH=1,4     TRANS
C                                                                        TRANS
C       LL = 8 MEANS NO LOW CLOUD                                        TRANS
C       MM = 4 MEANS NO MID CLOUD                                        TRANS
C       HH = 5 MEANS NO HI CLOUD                                         TRANS
C                                                                        TRANS
CLJ       EVALUATE LAYER PARAMETERS.  SORALT IS SOURCE ALTITUDE ABOVE    TRANS
CLJ       THE GROUND.  COUNT THE NUMBER OF LAYERS, NLAYER, ABOVE THE     TRANS
CLJ       SOURCE, INCLUDING THE ONE CONTAINING THE SOURCE.               TRANS
C       GET HORIZONTAL DISTANCE OF SOURCE FROM POINT OF                  TRANS
C       INTERSECTION OF LOS AND CLOUD TOP...RDIST                        TRANS
C                                                                        TRANS
C       MAKE NO CALCULATIONS FOR SUN BELOW HORIZON                       TRANS
      TRANSF = 0.                                                        TRANS
      IF( ITFLAG.EQ.0 )  RETURN                                          TRANS
CLJ       DETERMINE INDEX OF CLOUD IN HIGHEST LAYER PRESENT.             TRANS
      KCLOUD = HH + 10                                                   TRANS
      IF(HH .LT. 5) GO TO 4                                              TRANS
      KCLOUD = MM + 7                                                    TRANS
      IF(MM .LT. 4) GO TO 4                                              TRANS
      KCLOUD = LL                                                        TRANS
    4 CLDTOP = CLDBASE(KCLOUD) + CLDTHK(KCLOUD)                          TRANS
CLJ       DETERMINE RDIST AND OTHER GEOMETRICAL QUANTITIES FOR           TRANS
CLJ       ABOVE-IDENTIFIED CLOUD.                                        TRANS
      CALL SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,                      TRANS
     $  RDIST,SDIST,THETI,THETE,PHIE)                                    TRANS
      SORALT = HSORCE(NSORCE)                                            TRANS
      AZPU = 0.                                                          TRANS
      NLAYER = 0                                                         TRANS
CLJ       SKIP TO 10 IF NO LOW-LAYER CLOUD OR IF IT IS BELOW SOURCE.     TRANS
      IF(LL .GT. 7) GO TO 10                                             TRANS
      IF(SORALT .GT. CLDBASE(LL) + CLDTHK(LL) ) GO TO 10                 TRANS
      NLAYER = NLAYER + 1                                                TRANS
      THKN(NLAYER ) = CLDTHK(LL)                                         TRANS
CLJ       RESET THKN(NLAYER) BY TRUNCATING PORTION OF CLOUD BELOW SOURCE TRANS
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          IF(SORALT .GT. CLDBASE(LL) ) THKN(NLAYER) = CLDTHK(LL) +           TRANS
         1  CLDBASE(LL) - SORALT                                              TRANS
CLJ          AZRO = DISTANCE OF SOURCE BELOW BOTTOM OF LOWEST-ALTITUDE        TRANS
CLJ                 CLOUD LAYER.                                              TRANS
          IF(SORALT .LT. CLDBASE(LL)) AZRO = CLDBASE(LL) - SORALT             TRANS
CLJ          CORRELATE CLOUD-TYPE DIFFUSION PARAMETERS WITH LAYER DIFFUSION   TRANS
CLJ          PARAMETERS.                                                      TRANS
          DALFAN(NLAYER) = DALFA(LL)                                          TRANS
          DBETAN(NLAYER) = DBETA(LL)                                          TRANS
          DKAPPAN(NLAYER) = DKAPPA(LL)                                        TRANS
CLJ          CORRELATE CLOUD-TYPE INDEX WITH LAYER INDEX.                     TRANS
          LINDEX(NLAYER) = LL                                                 TRANS
CLJ          SET ALTITUDE OF BOTTOM OF CLOUD NLAYER=1                         TRANS
          A(NLAYER) = AMAX1(CLDBASE(LL),SORALT)                               TRANS
CLJ          SET ALTITUDE OF TOP OF CLOUD NLAYER=1                            TRANS
          A(NLAYER+1) = A(NLAYER) + THKN(NLAYER)                              TRANS
       10 CONTINUE                                                            TRANS
CLJ          SKIP TO 20 IF NO MID-LAYER CLOUD OR IF IT IS BELOW SOURCE.       TRANS
          IF(MM .GT. 3) GO TO 20                                              TRANS
          IF(SORALT .GT. CLDBASE(MM+7) + CLDTHK(MM+7) ) GO TO 20              TRANS
          NLAYER = NLAYER + 1                                                 TRANS
          THKN(NLAYER ) = CLDTHK(MM+7)                                        TRANS
CLJ          RESET THKN(NLAYER) BY TRUNCATING PORTION OF LAYER BELOW SOURCE   TRANS
          IF(SORALT .GT. CLDBASE(MM+7) ) THKN(NLAYER) = CLDTHK(MM+7) +        TRANS
         1  CLDBASE(MM+7) - SORALT                                            TRANS
          IF(SORALT .LT. CLDBASE(MM+7) .AND. NLAYER .EQ. 1)                   TRANS
         1 AZRO = CLDBASE(MM+7) - SORALT                                      TRANS
CLJ          CORRELATE CLOUD-TYPE DIFFUSION PARAMETERS WITH LAYER DIFFUSION   TRANS
CLJ          PARAMETERS.                                                      TRANS
          DALFAN(NLAYER) = DALFA(MM+7)                                        TRANS
          DBETAN(NLAYER) = DBETA(MM+7)                                        TRANS
          DKAPPAN(NLAYER) = DKAPPA(MM+7)                                      TRANS
CLJ          CORRELATE CLOUD-TYPE INDEX WITH LAYER INDEX.                     TRANS
          LINDEX(NLAYER) = MM + 7                                             TRANS
CLJ          SET ALTITUDE OF BOTTOM OF CLOUD NLAYER=1                         TRANS
          IF(NLAYER .EQ. 1) A(NLAYER) = AMAX1(CLDBASE(MM+7),SORALT)           TRANS
CLJ          SET ALTITUDE OF TOP OF CLOUD NLAYER+1                            TRANS
          A(NLAYER+1) = AMAX1(CLDBASE(MM+7),SORALT) + THKN (NLAYER)           TRANS
       20 CONTINUE                                                            TRANS
CLJ          SKIP TO 30 IF NO HIGH-LAYER CLOUD OR IF IT IS BELOW SOURCE.      TRANS
          IF(HH .GT. 4) GO TO 30                                              TRANS
          IF(SORALT .GT. CLDBASE(HH+10) + CLDTHK(HH+10) ) GO TO 30            TRANS
          NLAYER = NLAYER + 1                                                 TRANS
          THKN(NLAYER ) = CLDTHK(HH+10)                                       TRANS
          IF(SORALT .GT. CLDBASE(HH+10) ) THKN(NLAYER) = CLDTHK(HH+10) +      TRANS
         1  CLDBASE(HH+10) - SORALT                                           TRANS
          IF(SORALT .LT. CLDBASE(HH+10) .AND.  NLAYER .EQ. 1)                 TRANS
         1 AZRO = CLDBASE(HH+10) - SORALT                                     TRANS
          DALFAN(NLAYER) = DALFA(HH+10)                                       TRANS
          DBETAN(NLAYER) = DBETA(HH+10)                                       TRANS
          DKAPPAN(NLAYER) = DKAPPA(HH+10)                                     TRANS
          LINDEX(NLAYER) = HH + 10                                            TRANS
          IF(NLAYER .EQ. 1) A(NLAYER) = AMAX1(CLDBASE(HH+10),SORALT)          TRANS
          A(NLAYER+1) = AMAX1(CLDBASE(HH+10),SORALT) + THKN (NLAYER)          TRANS
       30 CONTINUE                                                            TRANS
C            CHECK FOR 1,2, OR 3 LAYERS                                       TRANS
C            IF THERE IS ONLY ONE LAYER, USE FORMALISM PREVIOUSLY DEVELOPED   TRANS
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C                                                                       TRANS     172
C        IF NO LAYERS ABOVE, WE HAVE AN ALBEDO FROM THE TOP LAYER       TRANS     173
C        IN THE LL,MM,HH COMBINATION.                                   TRANS     174
      IF(NLAYER .EQ. 0) GO TO 400                                       TRANS     175
CLJ      T1 = THICKNESS OF LAYER-1.                                     TRANS     176
      T1 = A(2) - A(1)                                                  TRANS     177
CLJ      RE-LABEL DIFFUSION PARAMETERS FOR LAYER-1.                     TRANS     178
      DA1 = DALFAN(1)                                                   TRANS     179
      DB1 = DBETAN(1)                                                   TRANS     180
      DK1 = DKAPPAN(1)                                                  TRANS     181
      IF(NLAYER .EQ. 1 .AND. AZRO .EQ. 0.) T1 = CLDTHK(LINDEX(NLAYER))  TRANS     182
      IF(NLAYER .EQ. 1) GO TO 100                                       TRANS     183
      T2 = A(3) - A(2)                                                  TRANS     184
CLJ      SCALE DIFFUSION PARAMETERS BETA AND KAPPA TO ACCOUNT FOR       TRANS     185
CLJ      ADJUSTED THICKNESS OF A HIGHER LAYER MADE CONTIGUOUS WITH A    TRANS     186
CLJ      LOWER LAYER.                                                   TRANS     187
CLJ      NOTE THAT DBETA (THE DIFFUSION COEFFICIENT) IS INVERSELY       TRANS     188
CLJ      PROPORTIONAL TO THE DENSITY (OR PROPORTIONAL TO THE RATIO      TRANS     189
CLJ      THK-NEW TO THK-OLD) AND DKAPPA (THE INVERSE DIFFUSION LENGTH)  TRANS     190
CLJ      IS PROPORTIONAL TO THE DENSITY (OR INVERSELY PROPORTIONAL TO   TRANS     191
CLJ      THE RATIO THK-NEW TO THK-OLD).  DALFA IS DIMENSIONLESS AND     TRANS     192
CLJ      REQUIRES NO CHANGE.                                            TRANS     193
      DA2 = DALFAN(2)                                                   TRANS     194
      DB2 = DBETAN(2) * T2 / THKN(2)                                    TRANS     195
      DK2 = DKAPPAN(2) * THKN(2) / T2                                   TRANS     196
      IF(NLAYER .EQ. 2) GO TO 200                                       TRANS     197
      T3 = A(4) - A(3)                                                  TRANS     198
CLJ      SCALE DIFFUSION PARAMETERS BETA AND KAPPA TO ACCOUNT FOR       TRANS     199
CLJ      ADJUSTED THICKNESS OF A HIGHER LAYER MADE CONTIGUOUS WITH A    TRANS     200
CLJ      LOWER LAYER.                                                   TRANS     201
      DA3 = DALFAN(3)                                                   TRANS     202
      DB3 = DBETAN(3) * T3 / THKN(3)                                    TRANS     203
      DK3 = DKAPPAN(3) * THKN(3) / T3                                   TRANS     204
      IF(NLAYER .EQ. 3) GO TO 300                                       TRANS     205
  100 CONTINUE                                                          TRANS     206
C                                                                       TRANS     207
C                                                                       TRANS     208
C                                                                       TRANS     209
C        ONE-LAYER  USE ORIGINAL FORMALISM                              TRANS     210
C                                                                       TRANS     211
C                                                                       TRANS     212
      IF(SORALT .LE. CLDBASE(LINDEX(1))) GO TO 105                      TRANS     213
C        FOR SOURCE INSIDE OF THE CLOUD                                 TRANS     214
      H = SORALT - CLDBASE(LINDEX(1))                                   TRANS     215
      FLUX = 0.                                                         TRANS     216
      PMIN = 1.E-20                                                     TRANS     217
      PMAX = 10. / T1                                                   TRANS     218
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)                  TRANS     219
      P = 1.E-10                                                        TRANS     220
      ANS = 0.                                                          TRANS     221
      DELTP = (PMAX - PMIN) / NNP                                       TRANS     222
      DSK1 = SQRT(DK1**2 + P**2 )                                       TRANS     223
      C = 1.                                                            TRANS     224
      CKT = EXP(DSK1 * T1)                                              TRANS     225
      CKH = EXP(DSK1 * H)                                               TRANS     226
      CKA = EXP(DSK1*(T1 - H))                                          TRANS     227
      SKT = 0.5 *(CKT - 1. / CKT)                                       TRANS     228
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CLJ       REDEFINE  CKT.                                          TRANS
      CKT = 0.5 *( CKT + 1. / CKT)                                TRANS
      SKH = 0.5 *(CKH - 1. / CKH)                                 TRANS
CLJ       REDEFINE  CKH.                                          TRANS
      CKH = 0.5 *(CKH + 1. / CKH)                                 TRANS
      SKA = 0.5 *(CKA - 1. / CKA)                                 TRANS
CLJ       REDEFINE  CKA.                                          TRANS
      CKA = 0.5 * (CKA + 1. / CKA)                                TRANS
      ANS = ANS + C*((DB1*DSK1 - DA1) / (DA1*(DB1*DSK1)**2 * 4. * TRANS
     1  (CKT + 0.5*(DA1/(DB1*DSK1) + DB1*DSK1/DA1) * SKT))        TRANS
     2 *((DA1 - DB1*DSK1)*(DA1*SKH + DB1*DSK1*CKH)                TRANS
     3 + (DA1 + DB1*DSK1)*(DA1*SKA + DB1*DSK1*CKA) * EXP(-DSK1*T1)) TRANS
     4  + EXP(-DSK1*(T1-H)) * (DA1 + DB1*DSK1) / (DB1*DSK1*2.))   TRANS
     5  * BESSO(P*RDIST) * P                                      TRANS
      C = 2.                                                      TRANS
      DO 104 I = 1,NNP                                            TRANS
      P = P + DELTP                                               TRANS
      C = 6. - C                                                  TRANS
      CKT = EXP(DSK1 * T1)                                        TRANS
      CKH = EXP(DSK1 * H)                                         TRANS
      CKA = EXP(DSK1*(T1 - H))                                    TRANS
      SKT = 0.5 *(CKT - 1. / CKT)                                 TRANS
      CKT = 0.5 *( CKT + 1. / CKT)                                TRANS
      SKH = 0.5 *(CKH - 1. / CKH)                                 TRANS
      CKH = 0.5 *(CKH + 1. / CKH)                                 TRANS
      SKA = 0.5 *(CKA - 1. / CKA)                                 TRANS
      CKA = 0.5 * (CKA + 1. / CKA)                                TRANS
      ANS = ANS + C*((DB1*DSK1 - DA1) / (DA1*(DB1*DSK1)**2 * 4. * TRANS
     1  (CKT + 0.5*(DA1/(DB1*DSK1) + DB1*DSK1/DA1) * SKT))        TRANS
     2 *((DA1 - DB1*DSK1)*(DA1*SKH + DB1*DSK1*CKH)                TRANS
     3 + (DA1 + DB1*DSK1)*(DA1*SKA + DB1*DSK1*CKA) * EXP(-DSK1*T1)) TRANS
     4  + EXP(-DSK1*(T1-H)) * (DA1 + DB1*DSK1) / (DB1*DSK1*2.))   TRANS
     5  * BESSO(P*RDIST) * P                                      TRANS
  104 CONTINUE                                                    TRANS
      FLUX = ANS * DELTP / 3.                                     TRANS
C        CHECK UNITS HERE                                         TRANS
C                                                                 TRANS
C                                                                 TRANS
      GO TO 500                                                   TRANS
  105 CONTINUE                                                    TRANS
CLJ       CONSIDER THE CASE OF A POINT SOURCE BELOW A SINGLE-LAYER TRANS
CLJ       CLOUD.                                                  TRANS
CLJ       THE FOLLOWING STEPS EVALUATE THE INTEGRAL IN EQ. (30A) OF THE TRANS
CLJ       CLOUD REPORT.  THIS INTEGRAL (HERE GIVEN THE FORTRAN NAME TRANS
CLJ       FLUX), WHEN DIVIDED BY (4.*PI), WILL BE THE TRANSMITTED FLUX TRANS
CLJ       (OR BETTER, RADIANT EXITANCE OR EMITTANCE) FOR A UNIT-STRENGTH TRANS
CLJ       SOURCE EMITTING ISOTROPICALLY INTO 4*PI STERADIANS.     TRANS
      FLUX = 1.E-50                                               TRANS
      PMIN = 1.E-20                                               TRANS
      PMAX = 10. / (T1 + AZRO)                                    TRANS
CLJ       LIMIT THE NUMBER OF INTERVALS, NNP, IN THE SIMPSON-INTEGRATION TRANS
CLJ       RULE TO THE RANGE FROM 50 TO 200.  NO ATTEMPT IS MADE TO TRANS
CLJ       INSURE THAT NNP IS EVEN.                                TRANS
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)            TRANS
      DELTP = (PMAX - PMIN) / NNP                                 TRANS
      C = 1.000                                                   TRANS
CLJ       THE FOLLOWING P IS THE EFFECTIVE P-SUB-0.               TRANS
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      P = 1.E-10
      DSK1 = SQRT(DK1**2 + P**2)
CLJ       IF THE ARGUMENT OF THE SINH AND COSH FUNCTIONS EXCEEDS 100,
CLJ       SKIP THE INTEGRATION AND USE THE ABOVE-INITIALIZED VALUE OF
CLJ       FLUX TO SET AN ARBITRARILY SMALL VALUE.
      IF(DSK1 * T1 .GT. 100.) GO TO 111
      AL1 = DB1 * DK1 / DA1
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)
      FBAR = EXP(-P * AZRO )
      DENOM = 1. - AL1**2
CLJ       BY USING THE RELATION 1. = (COSH( ))**2 - (SINH( ))**2 IN
CLJ       DENOM, ONE CAN SHOW THAT DD1/DENOM IS THE DENOMINATOR IN THE
CLJ       INTEGRAL BEING EVALUATED.
      SIGMA = DD1 * FBAR / DENOM
CLJ       THE SECOND TERM IN THE FOLLOWING EXPRESSION IS FLUX-SUB-0.
      FLUX = FLUX + SIGMA * BESSO (P*RDIST) * P * C
      C = 2.
CLJ       IN DO-110, THE UPPER LIMIT SHOULD BE NNP-1 IF NNP IS EVEN.
CLJ       THE CONSEQUENCE IS THAT FLUX-SUB-NNP WILL BE GIVEN TWICE THE
CLJ       WEIGHT IT SHOULD HAVE.  IF NNP IS ODD, A DIFFERENT (SMALL)
CLJ       ERROR WILL RESULT.
      DO 110 I = 1,NNP
      P = P + DELTP
      C = 6. - C
      DSK1 = SQRT(DK1**2 + P**2)
      IF(DSK1 * T1 .GT. 100.) GO TO 111
      AL1 = DB1 * DK1 / DA1
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)
      FBAR = EXP(-P * AZRO )
      DENOM = 1. - AL1**2
      SIGMA = DD1 * FBAR / DENOM
      FLUX = FLUX + SIGMA * BESSO (P*RDIST) * P * C
  110 CONTINUE
  111 FLUX = FLUX * DELTP / 3.
C        CHECK UNITS HERE
C
C
      GO TO 500
C
C        TWO LAYERS INTEGRATE OVER P
C
  200 CONTINUE
      FLUX = 1.E-50
      PMIN = 1.E-20
      PMAX = 10. / (T1 + T2 + AZRO)
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)
      DELTP = (PMAX - PMIN) / NNP
      C = 1.000
      P = 1.E-10
      DSK1 = SQRT(DK1**2 + P**2)
      DSK2 = SQRT(DK2**2 + P**2)
      IF(DSK1 * DSK2 * T1 * T2 .GT. 100.) GO TO 121
      AL2 = DB2 * DK2 / DA2
      AL1 = DB1 * DK1 / DA1
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)
```

```
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)          TRANS
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                         TRANS
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                         TRANS
      FBAR = EXP(-P * AZRO )                                           TRANS
      DENOM = 1. - AL2**2 - AL1**2 - AL2*AL1*(DD2*DD1 - AL2*AL1)       TRANS
      SIGMA = DD2*DD1*FBAR/DENOM                                       TRANS
      FLUX = FLUX + SIGMA * BESSO (P*RDIST) * P * C                    TRANS
      C = 2.                                                           TRANS
      DO 120 I =  1,NNP                                                TRANS
      C = 6. - C                                                       TRANS
      P = P + DELTP                                                    TRANS
      DSK1 = SQRT(DK1**2 + P**2)                                       TRANS
      DSK2 = SQRT(DK2**2 + P**2)                                       TRANS
      IF(DSK1 * DSK2 * T1 * T2 .GT. 100.) GO TO 121                    TRANS
      AL1 = DB1 * DK1 / DA1                                            TRANS
      AL2 = DB2 * DK2 / DA2                                            TRANS
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)          TRANS
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)          TRANS
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                         TRANS
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                         TRANS
      FBAR = EXP(-P * AZRO )                                           TRANS
      DENOM = 1. - AL2**2 - AL1**2 - AL2*AL1*(DD2*DD1 - AL2*AL1)       TRANS
      SIGMA = DD2*DD1*FBAR/DENOM                                       TRANS
      FLUX = FLUX + SIGMA * BESSO (P*RDIST) * P * C                    TRANS
  120 CONTINUE                                                         TRANS
  121 FLUX = FLUX * DELTP / 3.                                         TRANS
C        UNITS FOR FLUX ARE (1/KM**2)                                  TRANS
C                                                                      TRANS
C                                                                      TRANS
      GO TO 500                                                        TRANS
  300 CONTINUE                                                         TRANS
C                                                                      TRANS
C        THREE LAYERS                                                  TRANS
C                                                                      TRANS
      FLUX = 1.E-50                                                    TRANS
      PMIN = 1.E-20                                                    TRANS
      PMAX = 10. / (T1 + T2 + T3 + AZRO)                               TRANS
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)                 TRANS
      DELTP = (PMAX - PMIN) / NNP                                      TRANS
      C = 1.000                                                        TRANS
      P = 1.E-10                                                       TRANS
      AL1 = DB1 * DK1 / DA1                                            TRANS
      AL2 = DB2 * DK2 / DA2                                            TRANS
      AL3 = DB3 * DK3 / DA3                                            TRANS
      DSK1 = SQRT(DK1**2 + P**2)                                       TRANS
      DSK2 = SQRT(DK2**2 + P**2)                                       TRANS
      DSK3 = SQRT(DK3**2 + P**2)                                       TRANS
      IF(DSK1*DSK2*DSK3 * T1*T2*T3 .GT. 100.) GO TO 131                TRANS
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)          TRANS
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)          TRANS
      DD3 = COSH(DSK3*T3) - 0.5*(1./AL3+AL3) * SINH(DSK3*T3)          TRANS
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                         TRANS
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                         TRANS
      AL3 = 0.5*(1./AL3 - AL3) * SINH(DSK3*T3)                         TRANS
      FBAR = EXP(-P * AZRO )                                           TRANS
      DENOM = 1. - AL1**2 - AL2**2 - AL3**2                            TRANS
     1  -AL1*AL2*(DD2*DD1-AL2*AL1) - AL2*AL3*(DD3*DD2-AL3*AL2)         TRANS
```

```
     2 + AL1**2*AL3**2 -AL3*AL1*(DD3*DD2 - AL3*AL2)*(DD2*DD1 - AL2*AL1)
      SIGMA = DD3*DD2*DD1*FBAR / DENOM
      FLUX = FLUX + SIGMA * BESSO (P*RDIST) * P * C
      C = 2.
      DO 130 I = 1, NNP
      C = 6. - C
      P = P + DELTP
      AL1 = DB1 * DK1 / DA1
      AL2 = DB2 * DK2 / DA2
      AL3 = DB3 * DK3 / DA3
      DSK1 = SQRT(DK1**2 + P**2)
      DSK2 = SQRT(DK2**2 + P**2)
      DSK3 = SQRT(DK3**2 + P**2)
      IF(DSK1*DSK2*DSK3 * T1*T2*T3 .GT. 100.) GO TO 131
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)
      DD3 = COSH(DSK3*T3) - 0.5*(1./AL3+AL3) * SINH(DSK3*T3)
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)
      AL3 = 0.5*(1./AL3 - AL3) * SINH(DSK3*T3)
      FBAR = EXP(-P * AZRO )
      DENOM = 1. - AL1**2 - AL2**2 - AL3**2
     1 -AL1*AL2*(DD2*DD1-AL2*AL1) - AL2*AL3*(DD3*DD2-AL3*AL2)
     2 + AL1**2*AL3**2 -AL3*AL1*(DD3*DD2 - AL3*AL2)*(DD2*DD1 - AL2*AL1)
      SIGMA = DD3*DD2*DD1*FBAR / DENOM
      FLUX = FLUX + SIGMA * BESSO (P*RDIST) * P * C
  130 CONTINUE
  131 FLUX = FLUX * DELTP / 3.
C        UNITS FOR FLUX ARE (1/KM**2)
C
C
      GO TO 500
  400 CONTINUE
CLJ         NOW COMPUTE AIR TRANSMITTANCE FOR CASE THAT THE SOURCE IS
CLJ         ABOVE THE HIGHEST CLDTOP.
CLJ         IF THE SOURCE IS AN ARTIFICIAL ONE AND ITS ALTITUDE ABOVE
CLJ         CLDTOP IS LESS THAN THE RADIUS (RSORCE(1)) ASSIGNED TO THE
CLJ         FINITE-SIZE SOURCE, IT IS THEN NECESSARY TO RESET THE SOURCE
CLJ         ALTITUDE (SORALT) TO HSEFF AND HENCE ZS TO RE+HSEFF AND TO
CLJ         RECOMPUTE THE SOURCE ZENITH ANGLE (THIEFF) AND SOURCE-TO-
CLJ         INTERCEPT-POINT DISTANCE (SDEFF).
      ALT = SORALT - CLDTOP
      IF( ALT.GE.RSORCE(1) )  GO TO 450
      HSEFF = CLDTOP + 0.5*( ALT + RSORCE(1))
      CALL SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,RE+HSEFF,
     $           RDEFF,SDEFF,THIEFF,THETE,PHIE)
      SDIST = SDEFF
      THETI = THIEFF
      SORALT = HSEFF
  450 CONTINUE
      T1 = 1.0
      IF( SORALT.LT.12. )  T1 = TAIR(ALAM,THETI,SORALT)
      T2 = 1.0
      IF( CLDTOP.LT.12. )  T2 = TAIR(ALAM,THETI,CLDTOP)
      TSX = T2 / T1
      TDX = 1.0
      IF( CLDTOP.LT.12. )  TDX = TAIR(ALAM,THETE,CLDTOP)
```

```
      FLUX=CLDBDR(COS(THETI*DTR),COS(THETE*DTR),COS(PHIE*DTR)                   TRANS
     X    ,ALAM,KCLOUD)                                                         TRANS
      TPALT = 12.                                                               TRANS
CLJ        IN COMPUTING SDISTO WE USE THE ORIGINAL ZS, WITHOUT ANY              TRANS
CLJ        RESETTING IF THE SOURCE IS ARTIFICIAL, EVEN THOUGH ITS               TRANS
CLJ        ALTITUDE ABOVE CLDTOP MAY BE LESS THAN ITS RADIUS.                   TRANS
      CALL SGEOM(UL,VL,WL,TPALT,XD,YD,ZD,XS,YS,ZS,                              TRANS
     X    RDIST,SDISTO,THETIO,THETE,PHIE)                                       TRANS
      TRANSF = FLUX * TSX * TDX * COS(THETI/57.295) *(SDISTO/SDIST)**2          TRANS
      RETURN                                                                    TRANS
  500 CONTINUE                                                                  TRANS
CLJ        NOW COMPUTE AIR TRANSMITTANCE FOR CASE THAT THE SOURCE IS            TRANS
CLJ        BELOW THE HIGHEST CLDTOP.                                            TRANS
      THI = 180.-THETI                                                          TRANS
      T1 = TAIR(ALAM,THI,SORALT)                                                TRANS
      T2 = TAIR(ALAM,THI,CLDTOP)                                                TRANS
      TSX = T1 / T2                                                             TRANS
      TPALT = 12.                                                               TRANS
      CALL SGEOM(UL,VL,WL,TPALT,XD,YD,ZD,XS,YS,ZS,                              TRANS
     $    RDIST,SDISTO,THETI,THETEO,PHIE)                                       TRANS
      TDX = TAIR(ALAM,THETE,CLDTOP)                                             TRANS
      TRANSF = FLUX * TSX * TDX / PI * SDISTO**2                                TRANS
      IF( TRANSF.GE.0.0 )  GO TO 600                                            TRANS
      WRITE(6,550)  TRANSF,RDIST                                                TRANS
  550 FORMAT (*0      WARNING ... WARNING ... WARNING                           TRANS
     1 *   (SUBROUTINE TRANSF)   */                                             TRANS
     2 *0     THE PROGRAM HAS COMPUTED A NEGATIVE VALUE FOR THE*,               TRANS
     3 * TRANSMITTANCE TRANSFER COEFFICIENT, TRANSF =*,E14.5/                   TRANS
     4 *      AT A LATERAL DISPLACEMENT OF RDIST =*,E14.5,* KM */               TRANS
     5 *      THE PROGRAM ALSO TOOK THE ABSOLUTE VALUE OF TRANSF AND*,          TRANS
     6 * PROCEEDED NORMALLY, TO FACILITATE THE USER */                          TRANS
     7 *      MAKING A NOMINAL RUN.  THE ABSOLUTE MAGNITUDE OF TRANSF*,         TRANS
     8 * IS LIKELY LESS THAN THE CORRECT VALUE, */                              TRANS
     9 *      BUT THE RESULTS AT SUCH A LARGE VALUE OF RDIST ARE NOT*/          TRANS
     A * RELIABLE BECAUSE THE INTERNAL INTEGRATION */                           TRANS
     B *      SCHEME WAS NOT INTENDED TO TREAT SUCH CASES.*)                    TRANS
      TRANSF = ABS( TRANSF )                                                    TRANS
  600 CONTINUE                                                                  TRANS
      RETURN                                                                    TRANS
      END                                                                       TRANS
```

```
      SUBROUTINE VSNORM(X,Y,Z,EN1,EN2,EN3,K)                            VSNORM   2
CLJ                                                                     VSNORM   3
CLJ   SUBROUTINE VSNORM COMPUTES THE COMPONENTS, IN THE K-TH CLOUD-     VSNORM   4
CLJ   CENTERED CARTESIAN COORDINATE SYSTEM, OF THE UNIT VECTOR NORMAL   VSNORM   5
CLJ   TO THE ELLIPSOIDAL-SURFACE POINT X,Y,Z.                           VSNORM   6
CLJ                                                                     VSNORM   7
CLJ   INPUT PARAMETERS                                                  VSNORM   8
CLJ      ARGUMENT LIST                                                  VSNORM   9
CLJ           X,Y,Z = COORDINATES OF AN ELLIPSOIDAL-SURFACE POINT IN THE VSNORM  10
CLJ                   K-TH CLOUD-CENTERED CARTESIAN COORDINATE SYSTEM   VSNORM  11
CLJ               K = CLOUD NUMBER                                      VSNORM  12
CLJ      CDCORD COMMON                                                  VSNORM  13
CLJ         FOLLOWING PARAMETERS ARE SET IN SUBROUTINE CLDGEOM FOR      VSNORM  14
CLJ         K=1,10                                                      VSNORM  15
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        VSNORM  16
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      VSNORM  17
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        VSNORM  18
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      VSNORM  19
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        VSNORM  20
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    VSNORM  21
CLJ   OUTPUT PARAMETERS                                                 VSNORM  22
CLJ      ARGUMENT LIST                                                  VSNORM  23
CLJ            EN1, = COMPONENTS, IN THE K-TH CLOUD-CENTERED CARTESIAN  VSNORM  24
CLJ            EN2,   COORDINATE SYSTEM, OF THE UNIT VECTOR NORMAL TO   VSNORM  25
CLJ            EN3    THE ELLIPSOIDAL-SURFACE POINT X,Y,Z.              VSNORM  26
CLJ                                                                     VSNORM  27
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD   2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD   3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD   4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD   5
      EN1 = X/ASQ(K)                                                    VSNORM  29
      EN2 = Y / BSQ(K)                                                  VSNORM  30
      EN3 = Z / CSQ(K)                                                  VSNORM  31
      R = SQRT(EN1**2 + EN2**2 + EN3**2 )                               VSNORM  32
      EN1 = EN1 / R                                                     VSNORM  33
      EN2 = EN2 / R                                                     VSNORM  34
      EN3 = EN3 / R                                                     VSNORM  35
      RETURN                                                            VSNORM  36
      END                                                               VSNORM  37
```

APPENDIX C

LISTING OF UPDATE CARDS NECESSARY FOR SAMPLE PROBLEMS

```
*IDENT TPROB1/4
*/     FOR PROGRAM ROSCOER
*INSERT ROSCOER.13
       COMMON/ TPM4 /  IFLAG4
       DIMENSION  RRR(161), RRTR(161,4)
*DELETE ROSCOER.94
       KKK = 0
       DO 9 J=1,4
       DO 9 I=1,161
       RRTR(I,J) = 0.0
     9 CONTINUE
     7 CONTINUE
       KKK = KKK+1
       IFLAG4 = -2
*DELETE ROSCOER.176
       PIDX2 = PI*DXX/2.0    $    JR = 161
       DO 301 I=1,JR
*DELETE ROSCOER.182
*INSERT ROSCOER.188
       RRR(I) = X
       RRTR(1,KKK) = T4
*DELETE      ROSCOER.192,ROSCOER.194
*DELETE      ROSCOER.206,ROSCOER.208
*INSERT ROSCOER.211
       WRITE(6,103)
   103 FORMAT (1H1,*  RANGE *,*       SC             AC             CI     *,
      $ *   SC-AC-CI   *,*  INT(  SC )     INT(  AC )     INT(  CI )   *,
      $ *   INT(TOTAL)   *)
       RSM1 = 0.0   $   RSM2 = 0.0   $   RSM3 = 0.0   $   RSM4 = 0.0
       WRITE(6,105)  RRR(1),(RRTR(1,J),J=1,4),RSM1,RSM2,RSM3,RSM4
   105 FORMAT (1X,F8.2,4E12.4,4E14.6)
       DO 110 I=2,JR
       RSM1 = RSM1 + PIDX2*( RRR(I)*RRTR(I,1) + RRR(I-1)*RRTR(I-1,1) )
       RSM2 = RSM2 + PIDX2*( RRR(I)*RRTR(I,2) + RRR(I-1)*RRTR(I-1,2) )
       RSM3 = RSM3 + PIDX2*( RRR(I)*RRTR(I,3) + RRR(I-1)*RRTR(I-1,3) )
       RSM4 = RSM4 + PIDX2*( RRR(I)*RRTR(I,4) + RRR(I-1)*RRTR(I-1,4) )
       WRITE(6,105)  RRR(I),(RRTR(I,J),J=1,4),RSM1,RSM2,RSM3,RSM4
   110 CONTINUE
*/     FOR SUBROUTINE DIFPRM
*INSERT DIFPRM.81
       DATA IF1234 / -1 /
*DELETE DIFPRM.105
       IF( IF1234 .GT. 0 )   GO TO 111
*DELETE DIFPRM.124
       IF( IF1234 .GT. 0 )   GO TO 27
*DELETE DIFPRM.149
       IF( IF1234 .GT. 0 )   GO TO 29
*INSERT DIFPRM.156
       IF1234 = +2
*/     FOR SUBROUTINE SCLOUD
*INSERT SCLOUD.157
       E4 = EMISS(1)
       IF( ISUN.EQ.0 )  T4 = TRANS(1)
       IF( ISUN.EQ.1 )  S4 = TRANS(1)
       HSORCE(1) = HSAVE
```

Figure C-1. Update IDENT for Problems 1 to 4.

```
      GO TO 30
*/    FOR FUNCTION TRANSF
*BEFORE TRANS.9
      COMMON/ TPM4 /  IFLAG4
*INSERT TRANS.11
      DATA  KCLDZ / 0 /
*INSERT TRANS.101
      IF( KCLOUD.EQ.KCLDZ )  GO TO 6
      KCLDZ = KCLOUD
      PRODKL = DKAPPA(KCLOUD) * CLDTHK(KCLOUD)
      ADIVKB = DALFA(KCLOUD) / (DKAPPA(KCLOUD)*DBETA(KCLOUD))
      T = 1.0 / (COSH(PRODKL) + 0.5*(ADIVKB + 1.0/ADIVKB)*SINH(PRODKL))
      WRITE(6,13)  KCLOUD, T
   13 FORMAT (*0   TOTAL TRANSMISSION FOR KCLOUD = *,I4,*  IS *,E12.4)
    6 CONTINUE
*INSERT TRANS.386
CLJ         THE MAIN PROGRAM INITIALIZES IFLAG4 TO A NEG. VALUE.
      IF( IFLAG4.GT.0 )  GO TO 1301
CLJ         FOR SAMPLE PROBLEM NO. 4 WE WANT TO EVALUATE THE ANALYTIC
CLJ         EXPRESSION FOR THE TOTAL (SPATIALLY-INTEGRATED) TRANSMITTANCE
CLJ         THROUGH THREE LAYERS ABOVE A POINT SOURCE.
CLJ         FIRST, EVALUATE THE TRANSMITTANCE S AND REFLECTANCE R FOR EACH
CLJ         OF THE THREE LAYERS SEPARATELY, PER EQS. (31A) AND (31B) IN
CLJ         CLOUD REPORT APPENDIX A.
      DK1T1 = DK1*T1
      DK2T2 = DK2*T2
      DK3T3 = DK3*T3
      HSKT1 = SINH(DK1T1)
      HSKT2 = SINH(DK2T2)
      HSKT3 = SINH(DK3T3)
      S1 = 1.0/( COSH(DK1T1) + 0.5*(1./AL1 + AL1)*HSKT1 )
      S2 = 1.0/( COSH(DK2T2) + 0.5*(1./AL2 + AL2)*HSKT2 )
      S3 = 1.0/( COSH(DK3T3) + 0.5*(1./AL3 + AL3)*HSKT3 )
      R1 = S1*0.5*(1./AL1 - AL1)*HSKT1
      R2 = S2*0.5*(1./AL2 - AL2)*HSKT2
      R3 = S3*0.5*(1./AL3 - AL3)*HSKT3
CLJ         NOW EVALUATE THE TOTAL TRANSMITTANCE FOR THE THREE-LAYER
CLJ         CASE, S123.
      S123 = S1*S2*S3/( (1.-R1*R2)*(1.-R2*R3) - R1*R3*S2*S2 )
      IFLAG4 = +2
      WRITE(6,1300)  S1,S2,S3,R1,R2,R3,S123
 1300 FORMAT (*0   TRANSMITTANCES AND REFLECTANCES FOR EACH OF THREE*,
     1 * CLOUDS ARE...*/*    T1,T2,T3 =*,3E14.5/*    R1,R2,R3 =*,3E14.5/
     2 *0   TRANSMITTANCE FOR THREE-LAYER COMBINATION IS...*,
     3 * T123 =*,E14.5)
 1301 CONTINUE
*DELETE TRANS.390
*DELETE TRANS.413
*DELETE TRANS.478
      TRANSF = FLUX / PI
*DELETE TRANS.480
*DELETE TRANS.493
```

Figure C-1. (Continued)

```
*IDENT TPROB/5
*/     FOR PROGRAM ROSCOER
*DELETE ROSCOER.176
       DO 301 I=1,1
*DELETE ROSCOER.201
*/     FOR SUBROUTINE CLDWT
*INSERT CLDWT.7
       DIMENSION  LLMH(160,3),ZCFLOS(160,4)
*INSERT CLDWT.123
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.138
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.153
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.173
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.191
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.209
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.228
       LLMH(IDX,1) = LL    $    LLMH(IDX,2) = MM    $    LLMH(IDX,3) = HH
       ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*BEFORE CLDWT.233
       WRITE(6,303)
   303 FORMAT (2H1 ,* IDX  LL   MM  HH  *,*    TRANS        EMISS    *,
      $ *    CC=2          CC=3          CC=4          CC=5          WT       *,
      $ *   WT(SUM)  *)
       RSUM = 0.0
       DO 310 IX=1,160
       RSUM = RSUM + WT(IX)
       WRITE(6,305)  IX,(LLMH(IX,I),I=1,3),TRANS(IX),EMISS(IX),
      $              (ZCFLOS(IX,I),I=1,4),WT(IX),RSUM
   305 FORMAT (2X,4I4,2X,8E12.4)
   310 CONTINUE
*/     FOR SUBROUTINE DIFPRM
*DELETE DIFPRM.105
*DELETE DIFPRM.124
*DELETE DIFPRM.149
*/     FOR SUBROUTINE SCLOUD
*INSERT SCLOUD.254
       WRITE(6,103)  IDX,TRANS(160),EMISS(160),WT(160)
   103 FORMAT (2H0 ,4X,* IDX = *,I5,5X,* TRANS(160) = *,E12.4,5X,
      $ * EMISS(160) = *,E12.4,5X,*   WT (160) = *,E12.4)
*INSERT SCLOUD.260
       WRITE(6,111)     SLGCLD,SLGCLR,SFR,THI,T12,T2TP,RDIST,SDISTO,
      $                THETI,THETE,PHIE
   111 FORMAT (*0     SLGCLD,SLGCLR,SFR,THI,T12,T2TP,RDIST,SDISTO,*,
      $ *THETI,THETE,PHIE*,/(5X,6E12.4))
       WRITE(6,113)  (TRANS(I),WT (I),I=1,II)
       WRITE(6,115)  (EMISS(I),WT1(I),I=1,II)
   113 FORMAT (*0  TRANS,WT  =*/(5X,8E12.4))
   115 FORMAT (*0  EMISS,WT1 =*/(5X,8E12.4))
*INSERT SCLOUD.266
       WRITE(6,117)  (WT(I),WT1(I),I=1,II)
   117 FORMAT (*0  WT,WT1 =*/(5X,8E12.4))
```

Figure C-2. Update IDENT for Problem 5.

```
*IDENT TPROB/6
*/    FOR PROGRAM ROSCOER
*INSERT ROSCOER.13
      COMMON/XX0000/  XCC(64),YCC(64),ZCC(64)
*DELETE ROSCOER.17
      DATA  SOLLAT, SOLLON / 0.0, -0.785398 /
*DELETE      ROSCOER.139,ROSCOER.140
      IF( I.EQ.1 )  WRITE(6,123)
  123 FORMAT (*1CLOUD    ALAM      TCOEF        EMISS          XCC      *,
     1 *      YCC           ZCC       *)
      WRITE(6,125)  KCLOUD(K),ALAM,TCOEF,TEMISS,XCC(I),YCC(I),ZCC(I)
  125 FORMAT (1X,I5,F8.2,E12.4,E12.4,3E12.4)
*/    FOR SUBROUTINE CLOUD2
*DELETE CLOUD2.72
*DELETE CLOUD2.84
*DELETE CLOUD2.96
*/    FOR SUBROUTINE CLOUD3
*DELETE CLOUD3.185
*DELETE       CLOUD3.216,CLOUD3.217
*/    FOR SUBROUTINE DIFFUS
*DELETE DIFFUS.143
*DELETE DIFFUS.165
*DELETE DIFFUS.222
*/    FOR SUBROUTINE LOS
*BEFORE LOSK.67
      COMMON/XX0000/  XCC(64),YCC(64),ZCC(64)
*INSERT LOSK.118
      XCC(L) = 0.0
      YCC(L) = 0.0
      ZCC(L) = 0.0
*INSERT LOSK.153
      XCC(LL) = XX(IC,JC)
      YCC(LL) = YY(IC,JC)
      ZCC(LL) = ZZ(IC,JC)
*INSERT LOSK.203
      XCC(LL) = XX(IC,JC)
      YCC(LL) = YY(IC,JC)
      ZCC(LL) = ZZ(IC,JC)
*INSERT LOSK.245
      XCC(LL) = XX(IC,JC)
      YCC(LL) = YY(IC,JC)
      ZCC(LL) = ZZ(IC,JC)
```

Figure C-3. Update IDENT for Problem 6.

APPENDIX D

TRANSMITTANCE AND REFLECTANCE OF TWO- AND THREE-LAYER PLANAR SLABS

To help validate the code it is valuable to compare the code's results with information obtained by other means. One type of calculation performed by the code is the computation of the photon flux emerging from one- two-, and three-layer slabs at a given lateral displacement from the vertical through the point source below the slabs.

Sample Problems 1 to 3 in Section 4-3 are for one-layer slabs and Problem 4 is for a three-layer slab. To provide a check on the code's operation for Problems 1 to 3, we used Equation (32a) in Appendix A for the spatially-integrated transmittance of a planar slab. By performing a spatial integration of the code-computed flux, we compared the code's result with the analytic result in Equation (32a). Problem 4, with its three layers, is more complicated. Hence, we need another exact, analytic expression for the transmittance of three layers, given the transmittance and reflectance of each of the three separate layers. We derive such a formula here; it is applied in Section 4-3.1.

The approach is to derive formulas for the transmittance and reflectance of two layers and then to apply the two-layer formulas to the three-layer configuration. The derivation is greatly facilitated by drawing an appropriate diagram, such as that in Figure D-1. The total transmitted flux is seen to be a geometric series:

$$T_{12} = T_2T_1 \, [1 + R_2R_1 + (R_2R_1)^2 + (R_2R_1)^3 + \ldots]$$

$$= \frac{T_2T_1}{1-R_2R_1} \tag{1}$$

Similarly, the reflectance from the lower layer includes a geometric series:

$$R_{12} = R_1 + T_1{}^2R_2 \, [1 + R_2R_1 + (R_2R_1)^2 + (R_2R_1)^3 + \ldots]$$

$$= R_1 + \frac{T_1{}^2R_2}{1-R_2R_1} \tag{2}$$

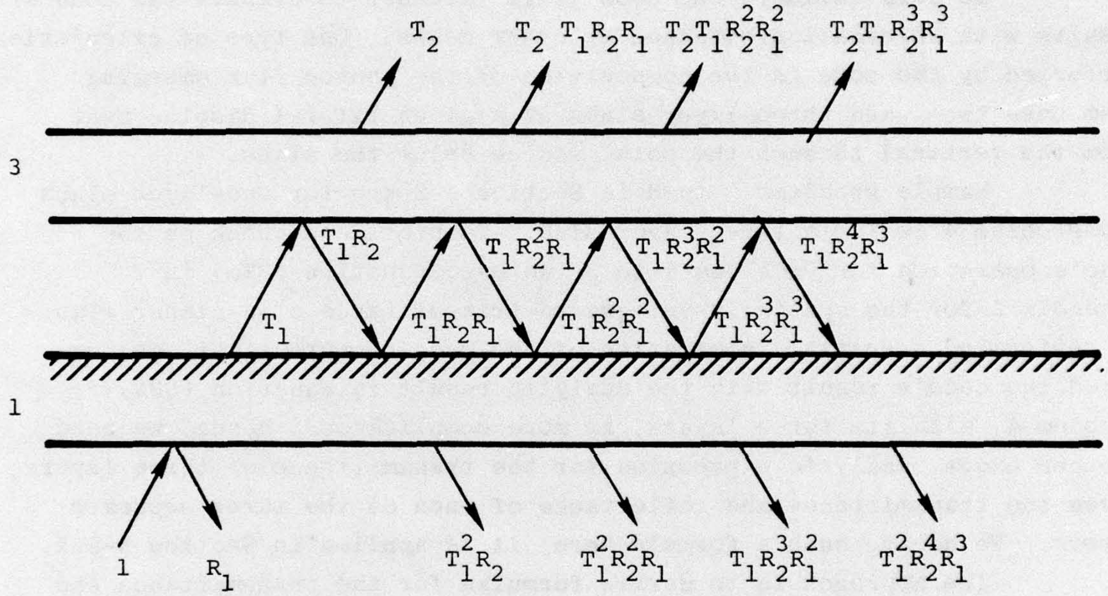

Figure D-1. Illustration of contributions to transmitted and reflected fluxes for a two-layer configuration.

Note that Equation (1) for the transmittance is symmetric in the indices 1 and 2 whereas Equation (2) for the reflectance is not symmetric.

If one makes the assumption of conservative scattering (i.e., no absorption), so that

$$T_1 + R_1 + 1$$

$$T_2 + R_2 = 1 \quad ,$$

then one can show that the reflectance is symmetric, i.e.,

$$R_{12} = R_{21} = \frac{R_1 + R_2 - 2R_1R_2}{1-R_1R_2}$$

and that

$$T_{12} + R_{12} + 1 \quad .$$

For three layers, consider Figure D-2 where we denote the pair of Layers 1 and 2 as Layer A and Layer 3 as Layer B. The symbol R_{A+} denotes the net reflectance for flux incident on the Layer-1 side of Layer A and R_{A-} denotes the net reflectance for flux incident on the Layer-2 side of Layer A.

The transmittance for flux incident on the Layer-1 side is

$$T_{AB} = T_BT_A \, [1 + R_BR_{A-} + (R_BR_{A-})^2 + \ldots]$$

$$= \frac{T_BT_A}{1-R_BR_{A-}} \quad .$$

The reflectance for flux incident on the Layer-1 side is

$$R_{AB} = R_{A+} + T_A{}^2R_B \, [1 + R_BR_{A-} + (R_BR_{A-})^2 + \ldots \,]$$

$$= R_{A+} + \frac{T_A{}^2R_B}{1-R_BR_{A-}} \quad .$$

By using the expressions

$$T_A = \frac{T_2T_1}{1-R_2R_1}$$

$$T_B = T_3$$

$$R_{A+} \equiv R_{12} = R_1 + \frac{T_1{}^2R_2}{1-R_2R_1}$$

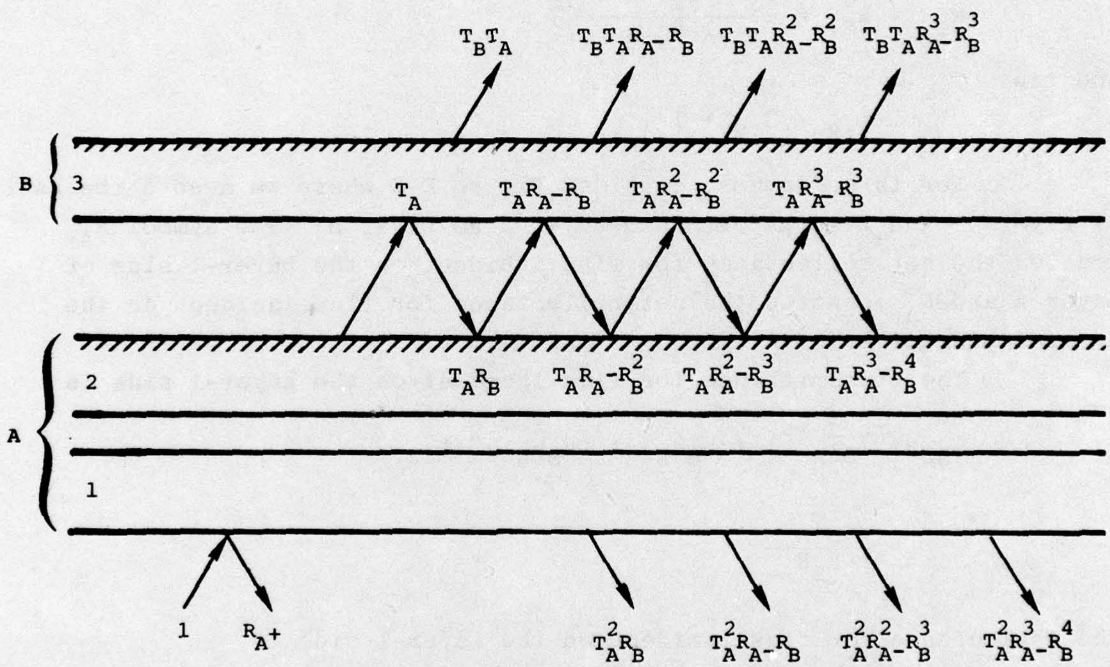

Figure D-2. Illustration of contributions to transmitted and reflected fluxes for a three-layer configuration expressed in terms of those for a two-layer configuration.

$$R_{A-} \equiv R_{21} = R_2 + \frac{T_2^{\,2} R_1}{1-R_1 R_2}$$

$$R_B = R_3$$

we find

$$T_{123} \equiv T_{AB} = \frac{T_3 T_2 T_1}{1-R_2 R_1} \; \frac{1}{1 - R_3 \left[R_2 + \dfrac{T_2^{\,2} R_1}{1-R_1 R_2} \right]}$$

$$\boxed{T_{123} = \frac{T_3 T_2 T_1}{(1-R_2 R_1)\,(1-R_3 R_2) - T_2^{\,2} R_3 R_1}}$$

which is symmetric with respect to an interchange of the 1 and 3 and hence is valid for the source irradiating either Layer 1 or Layer 3.

The reflectance R_{123} for a source below Layer 1 is

$$R_{123} \equiv R_{AB} = R_{A+} + \frac{T_A^{\,2} R_B}{1-R_B R_{A-}}$$

$$= R_1 + \frac{T_1^{\,2} R_2}{1-R_2 R_1} + \frac{\left(\dfrac{T_2 T_1}{1-R_2 R_1}\right)^2 R_3}{1 - R_3 \left[R_2 + \dfrac{T_2^{\,2} R_1}{1-R_1 R_2} \right]}$$

$$= \frac{R_1\,(1-R_2 R_1) + T_1^{\,2} R_2}{1-R_2 R_1}$$

$$+ \frac{\dfrac{(T_2 T_1)^2}{1-R_2 R_1}\, R_3}{(1-R_3 R_2)\,(1-R_2 R_1) - T_2^{\,2} R_3 R_1}$$

whereas the reflectance R_{321} for a source above Layer 3 is

$$R_{321} \equiv R_{BA} = R_B + \frac{T_B{}^2 R_{A-}}{1-R_B R_{A-}}$$

$$= R_3 + \frac{T_3{}^2 \left(R_2 + \frac{T_2{}^2 R_1}{1-R_1 R_2}\right)}{1 - R_3 \left[R_2 + \frac{T_2{}^2 R_1}{1-R_1 R_2}\right]} \; .$$

One can show that for conservative scattering, i.e.,

$$T_i + R_i = 1 \quad \text{for } i = 1,2,3 \quad ,$$

that

$$R_{123} = R_{321}$$

and

$$T_{123} + R_{123} = 1 \quad .$$

Finally, in Figure D-3 we illustrate the enhanced effective transmission of a single layer due to a reflecting surface located below the source. Let T be the transmittance of the layer without the reflecting surface. With the reflecting surface present, there are two contributions to the transmittance:

$$T_1 = T + TR^2 + TR^4 + \ldots = T/(1-R^2)$$

$$T_2 = TR + TR^3 + TR^5 + \ldots = TR/(1-R^2)$$

$$T_1+T_2 = T(1+R)/(1-R^2) = T/(1-R) \; .$$

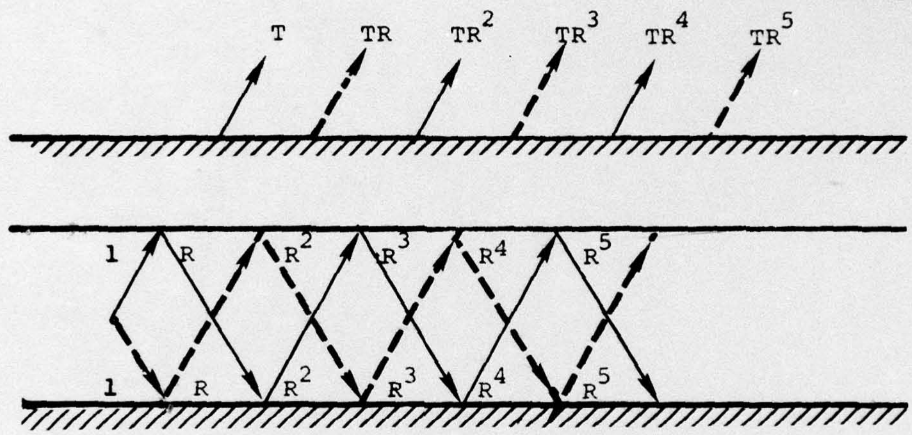

Figure D-3. Illustration of enhanced effective transmission of a single layer due to a reflecting surface.

The factor of increased transmittance due to the reflecting surface is

$$\frac{T_1+T_2}{T} = \frac{1}{1-R} \quad ,$$

a result stated in Section 2-2.

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